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(54) Abstract Title

**A downhole service tool**

(57) A downhole service tool 400 comprises an inflatable packer 410 and an imaging device 420 for analysing the quality of the bond between the packer element 412 and the formation 404. The imaging device 420 may be an acoustic sensor.

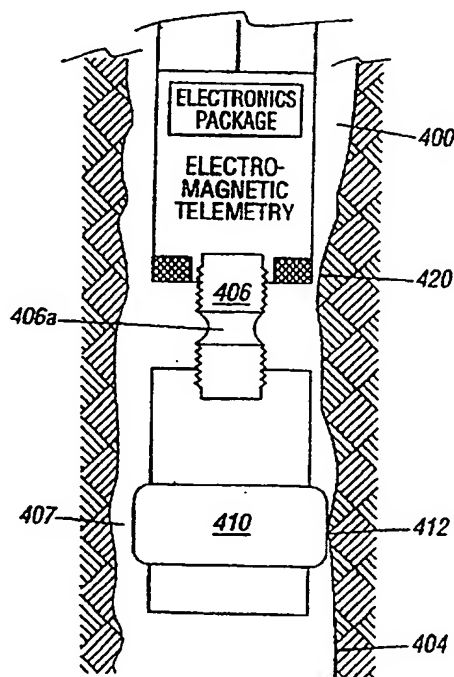
**FIG. 9**

FIG. 1

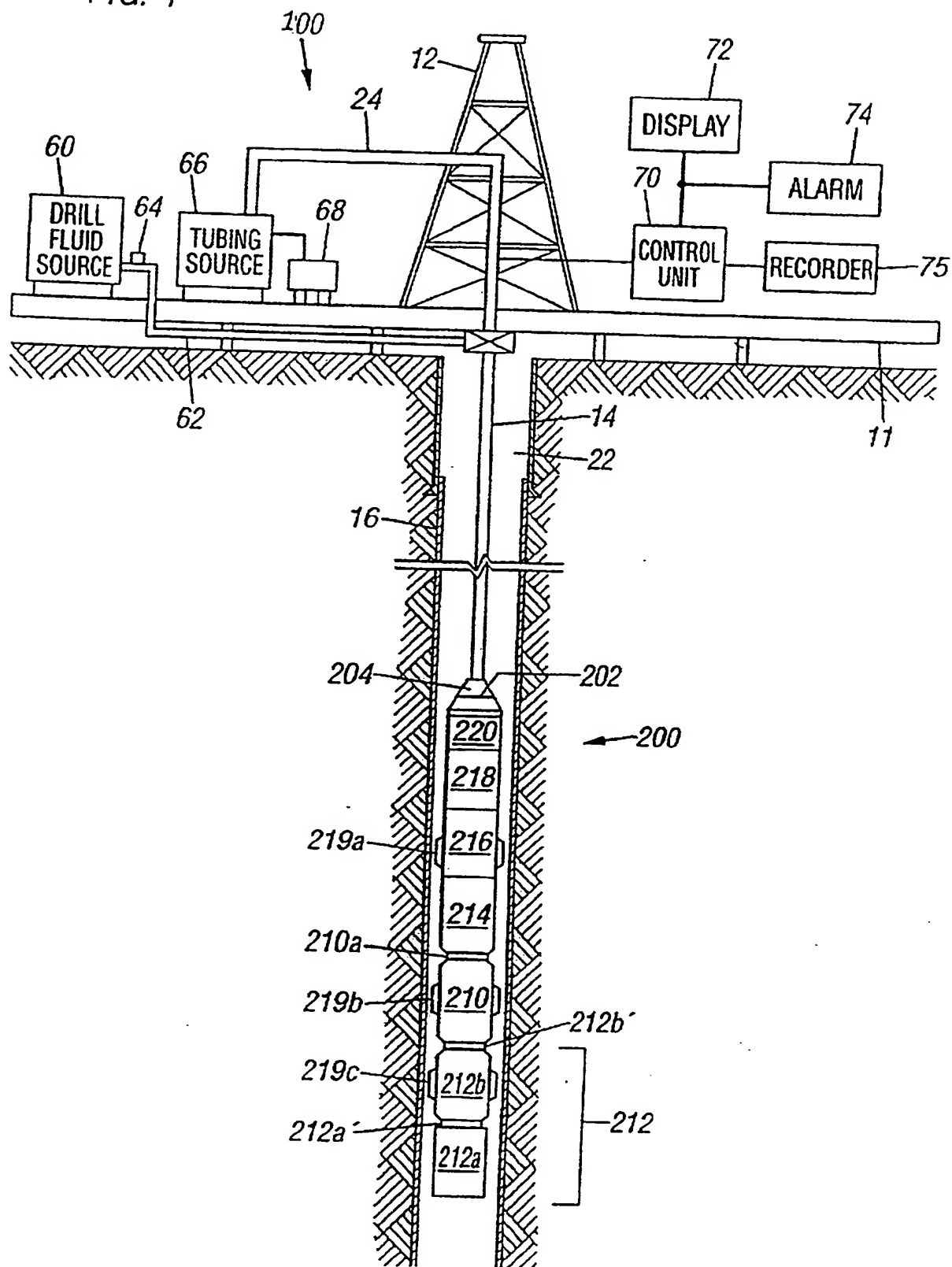


FIG. 2

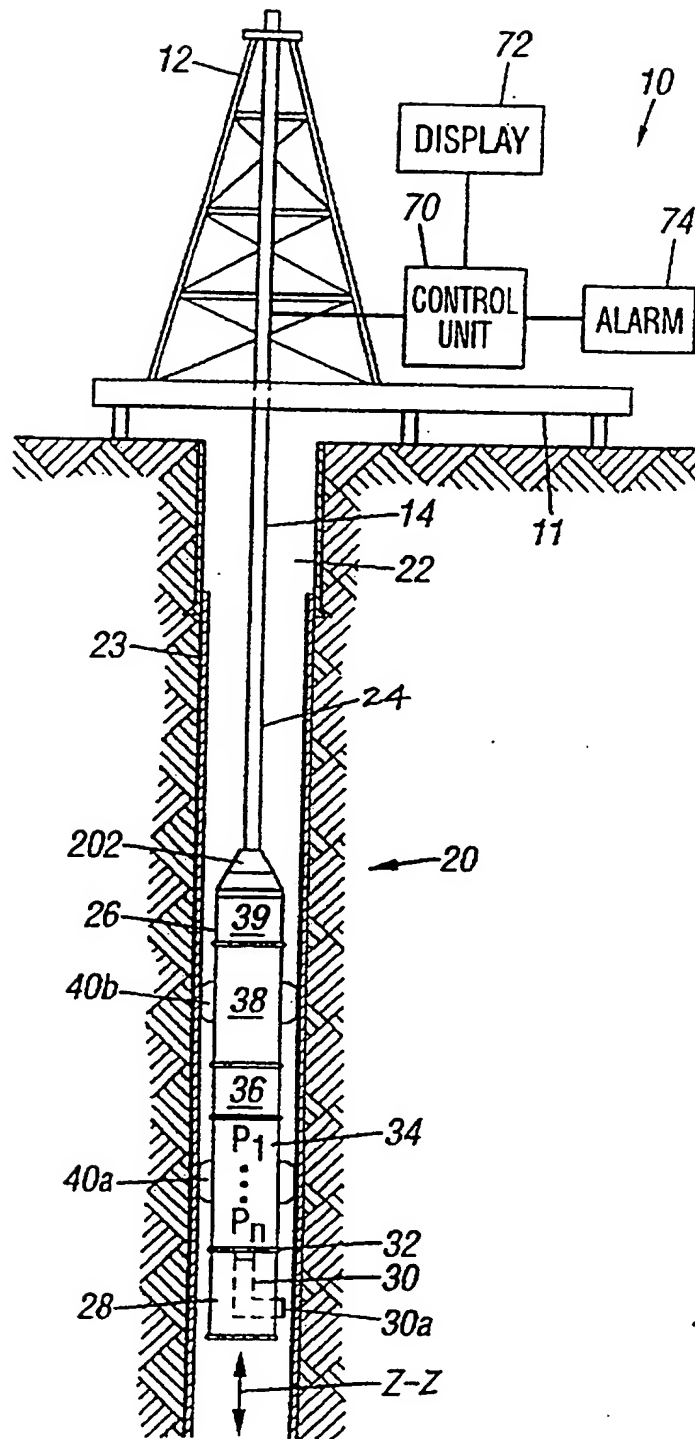


FIG. 1A

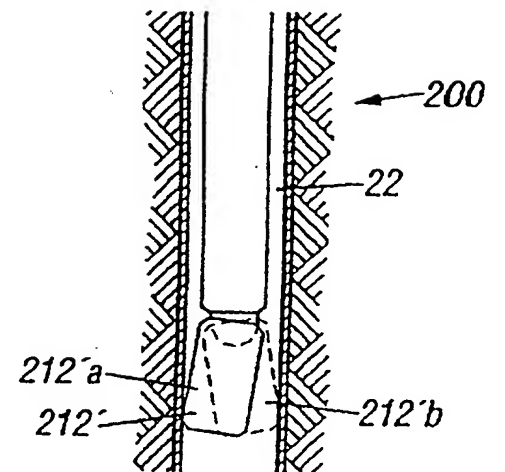


FIG. 2A

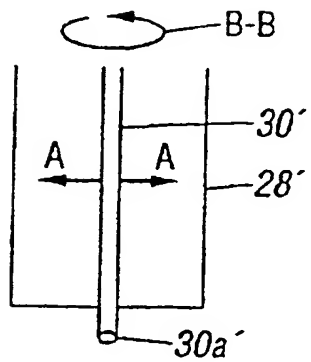


FIG. 3

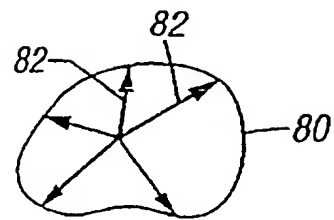


FIG. 4

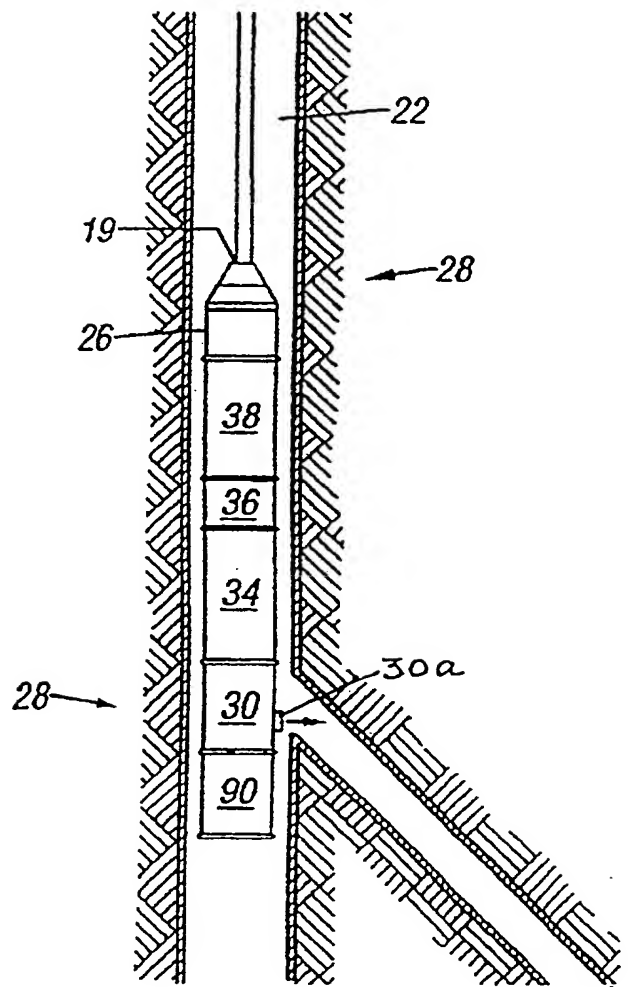


FIG. 2B

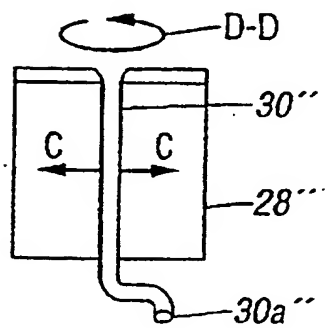


FIG. 2C

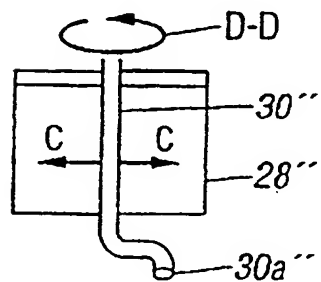


FIG. 5A

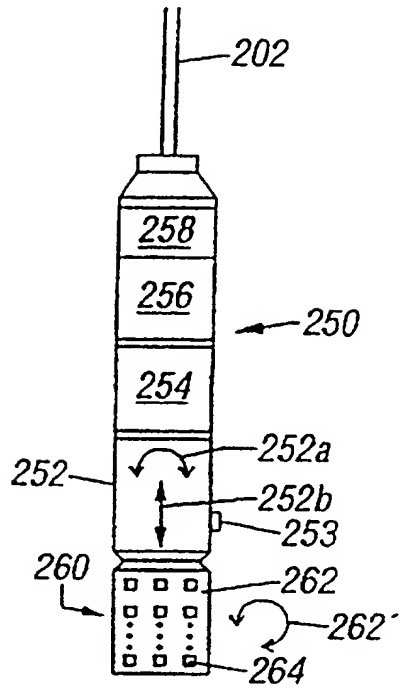


FIG. 5B

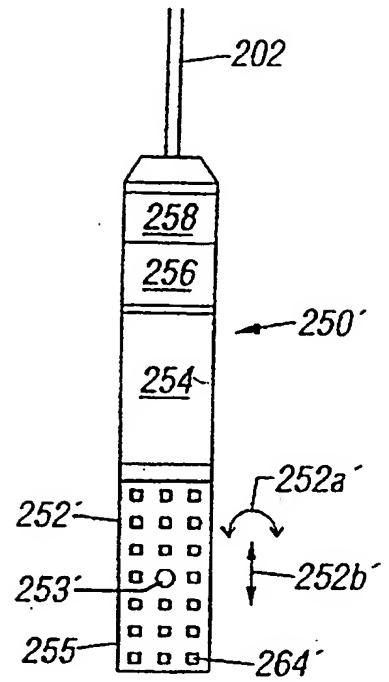


FIG. 5C

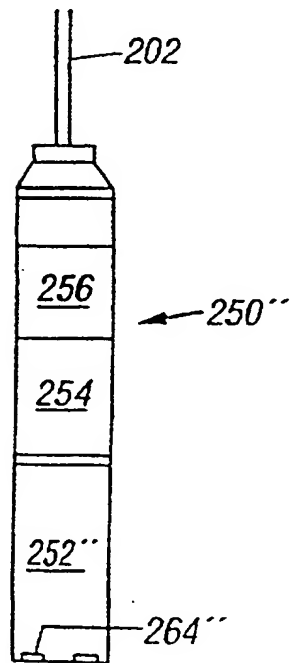


FIG. 5D

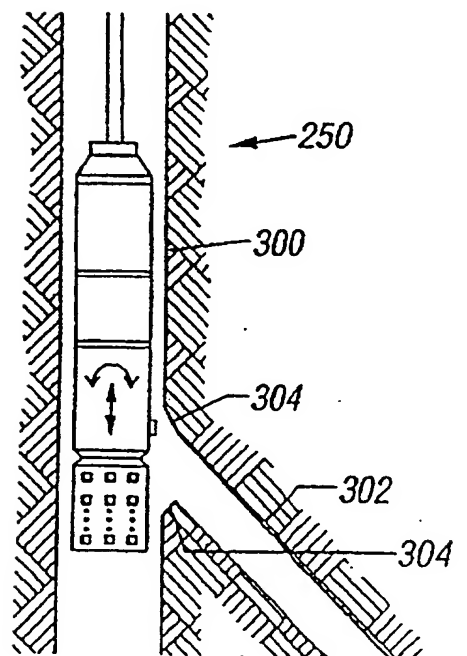


FIG. 6A

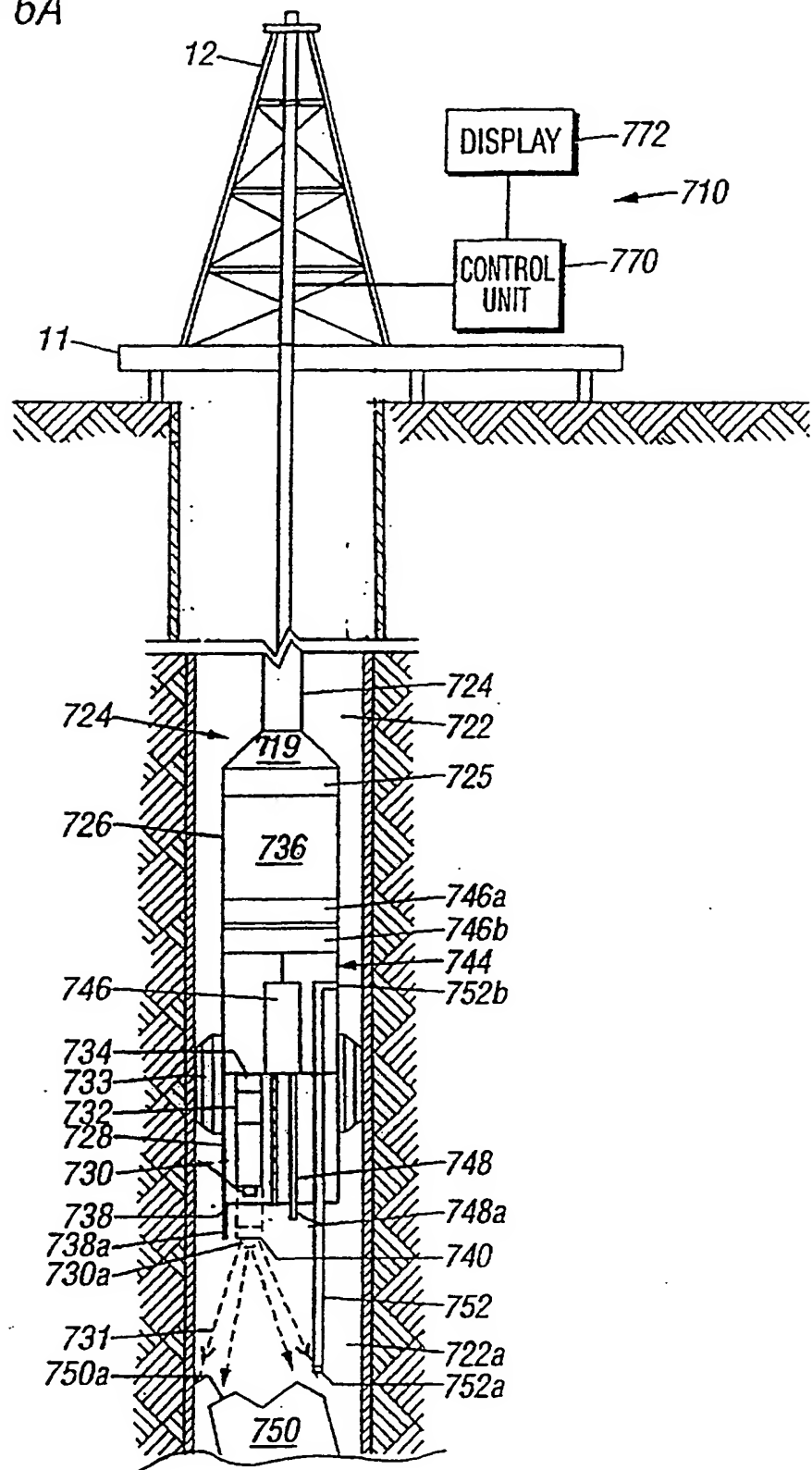


FIG. 6B

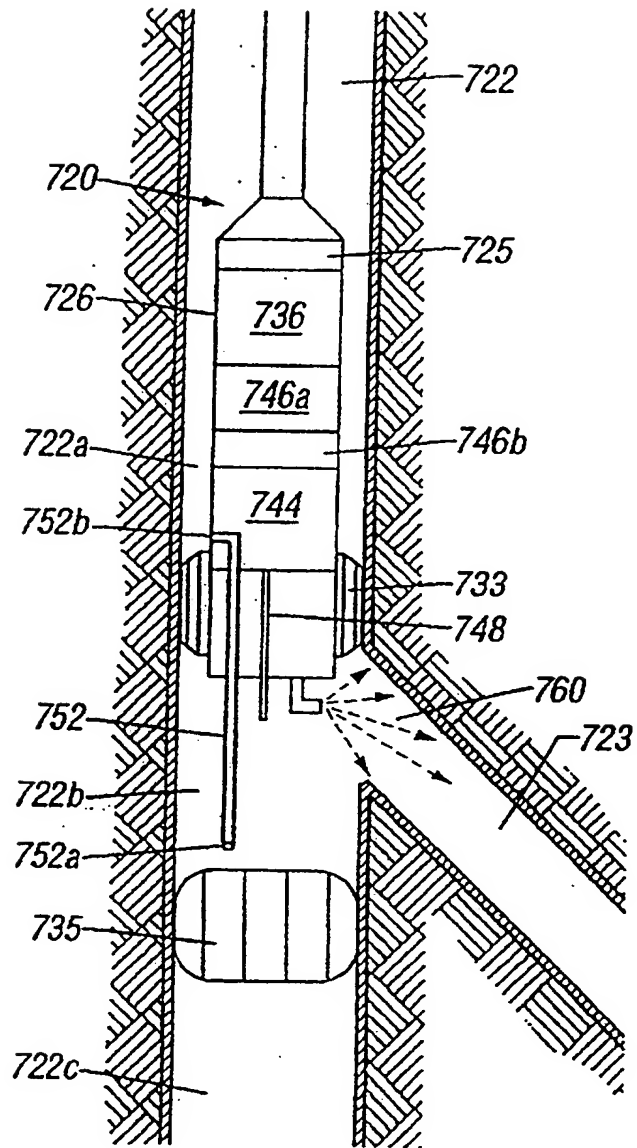


FIG. 6C

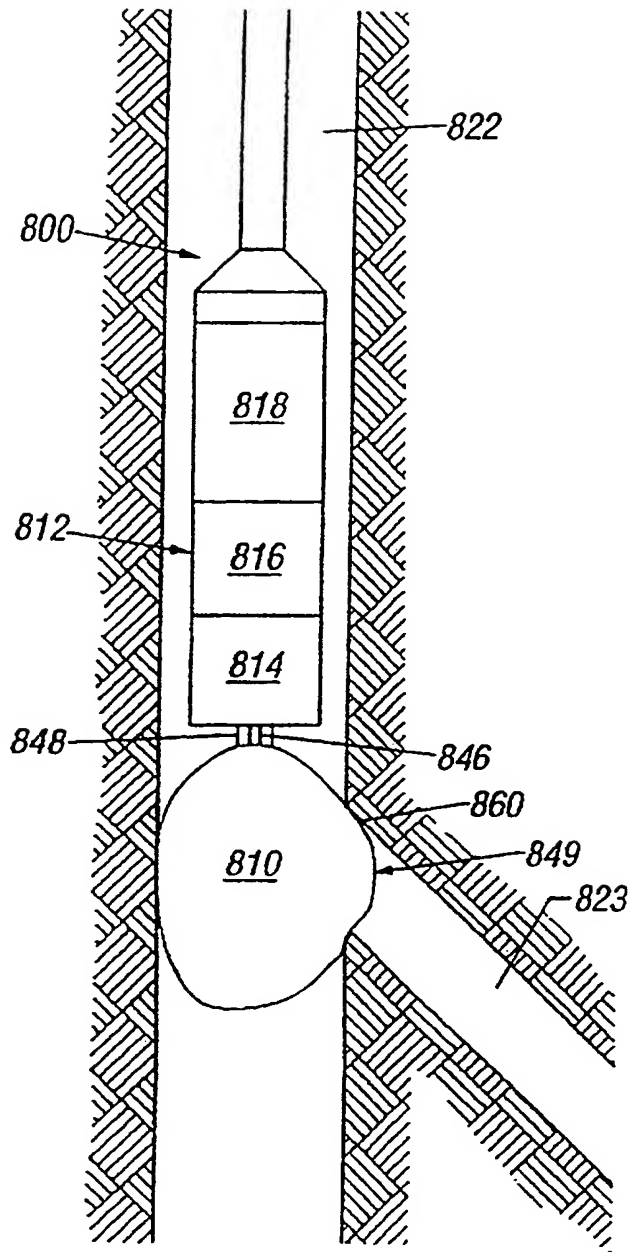


FIG. 6D

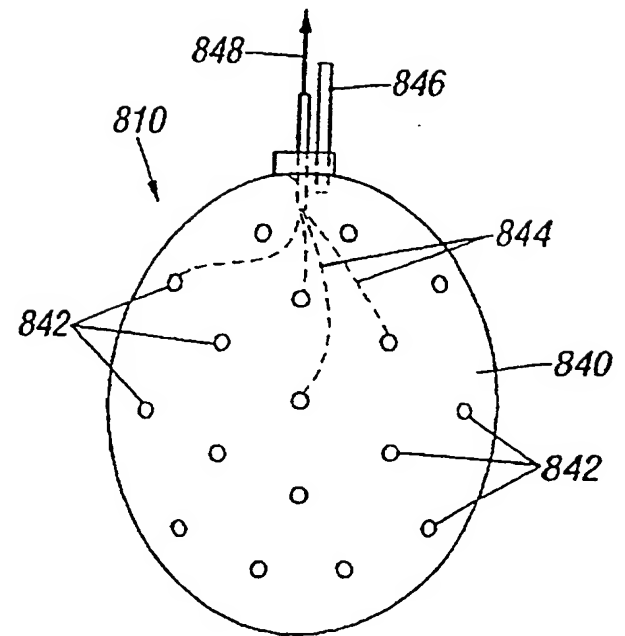




FIG. 7

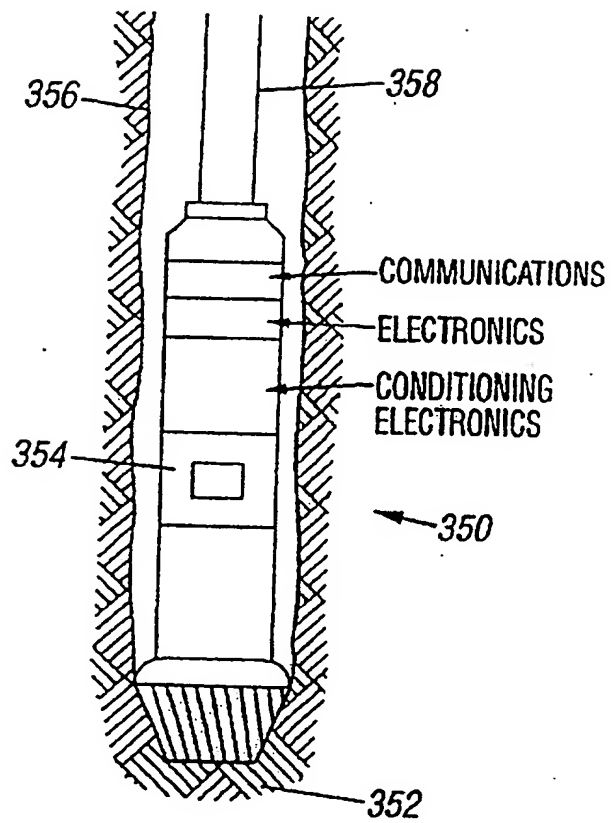


FIG. 8A

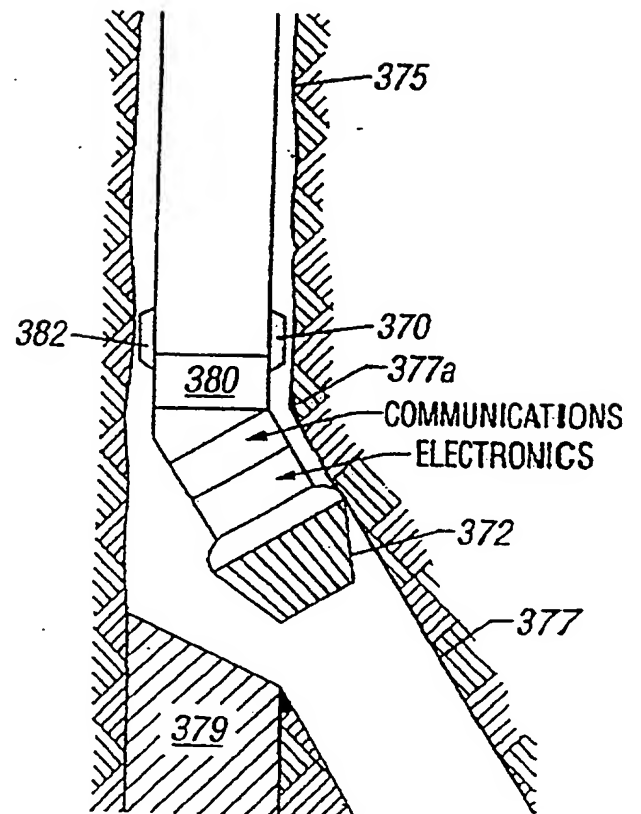


FIG. 8B

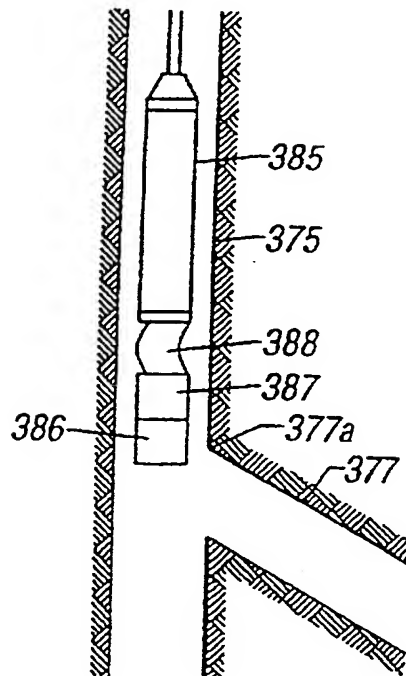


FIG. 8C

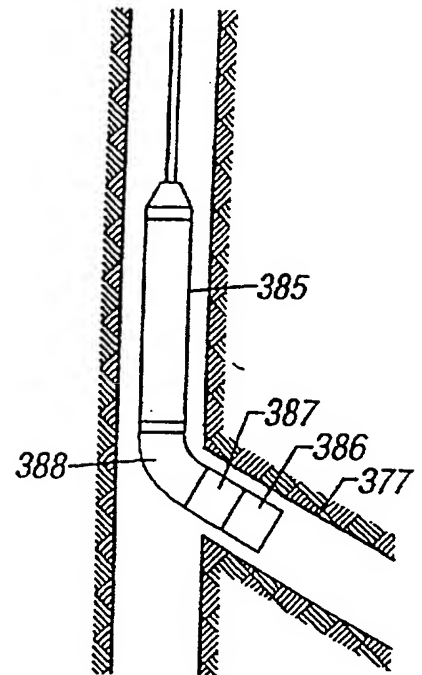


FIG. 8D

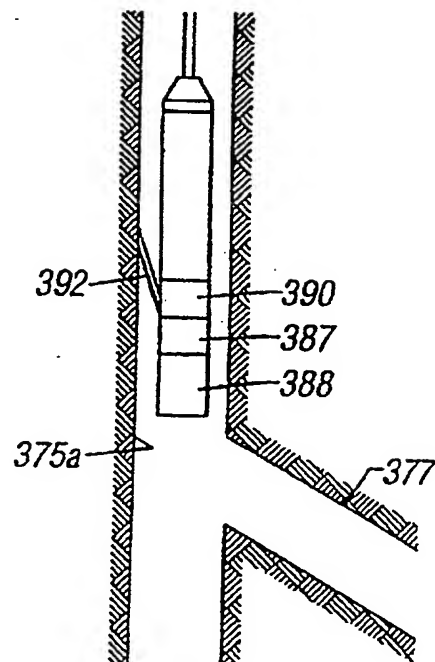


FIG. 9

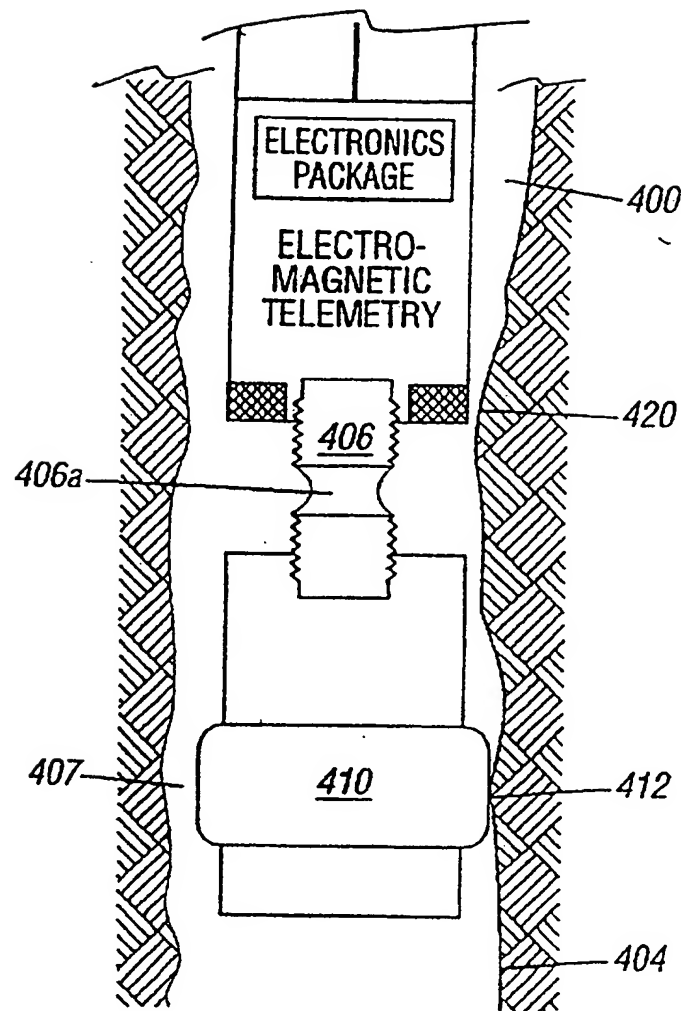


FIG. 10A

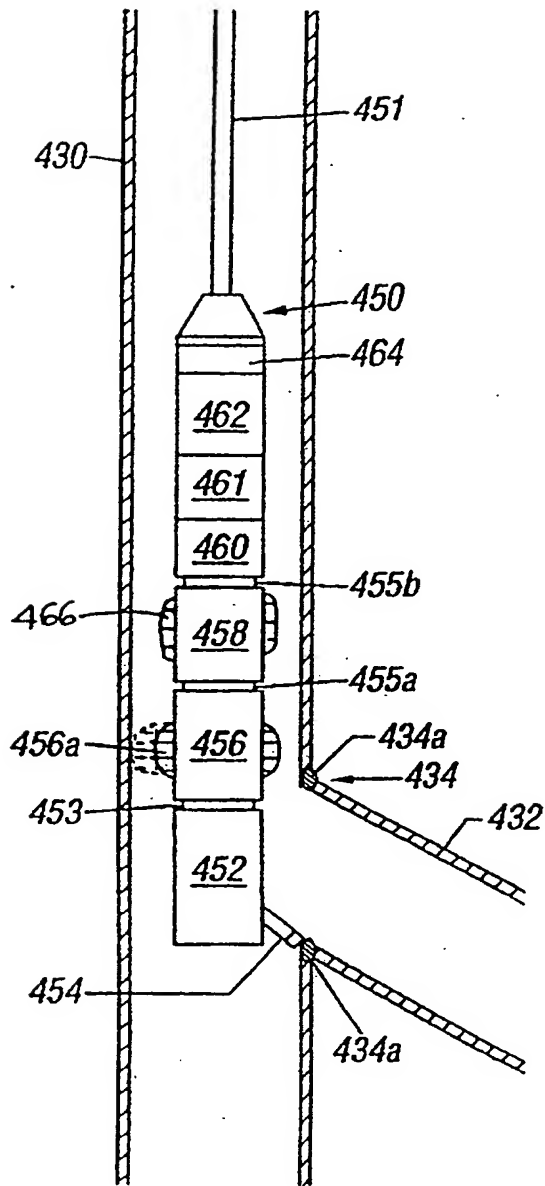


FIG. 10B

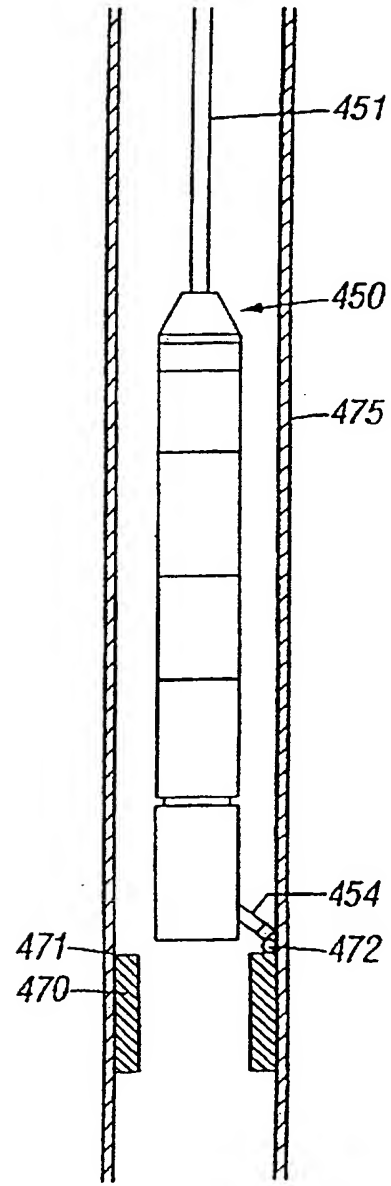


FIG. 11

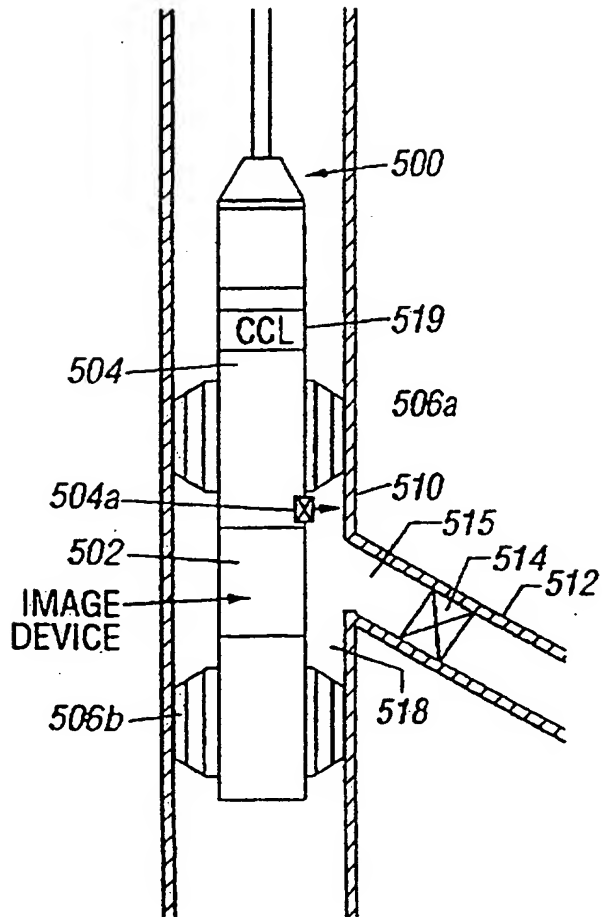


FIG. 12

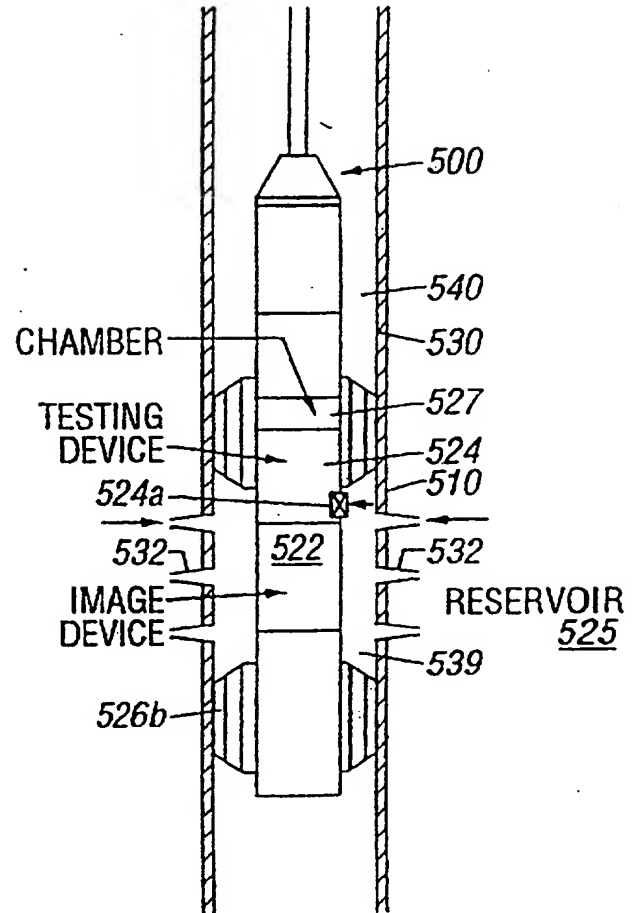


FIG. 13

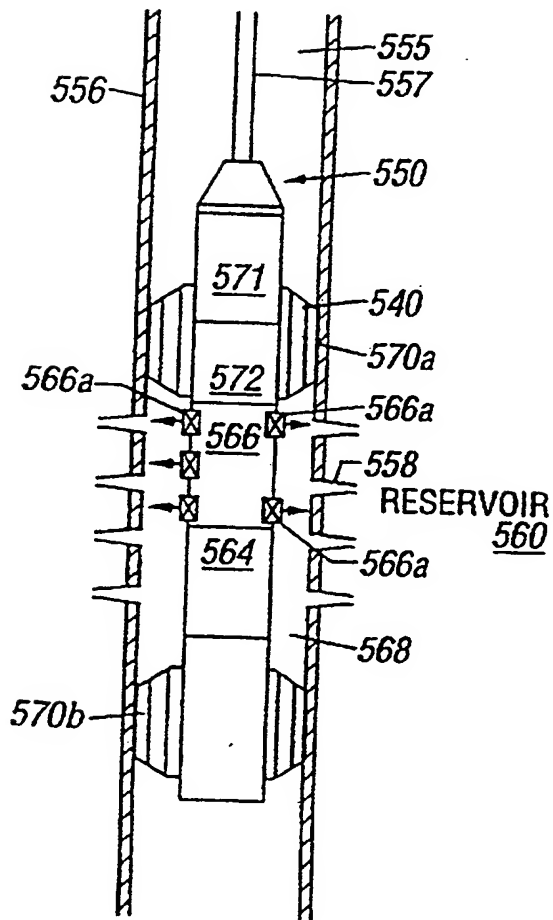


FIG. 14

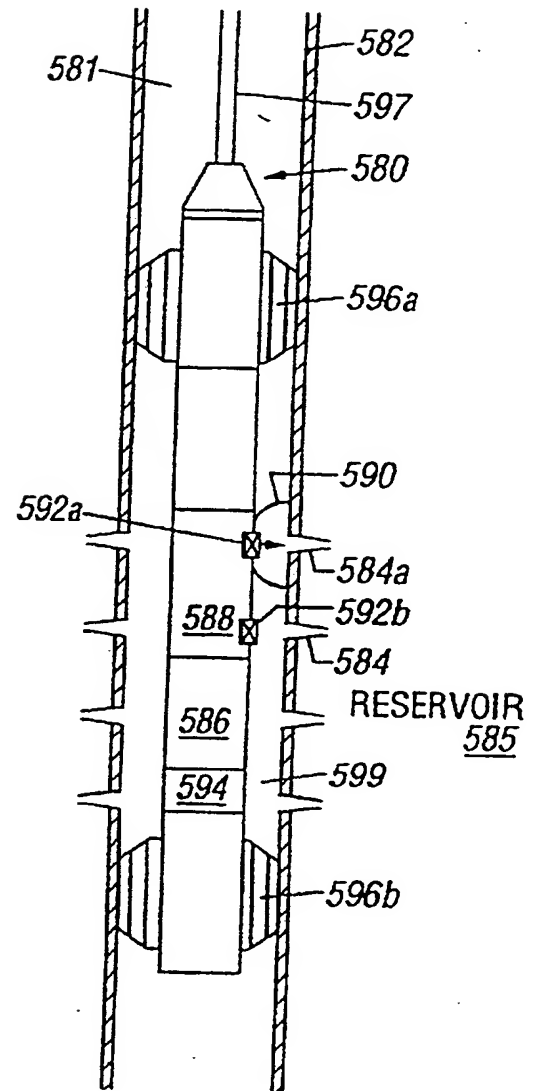


FIG. 15

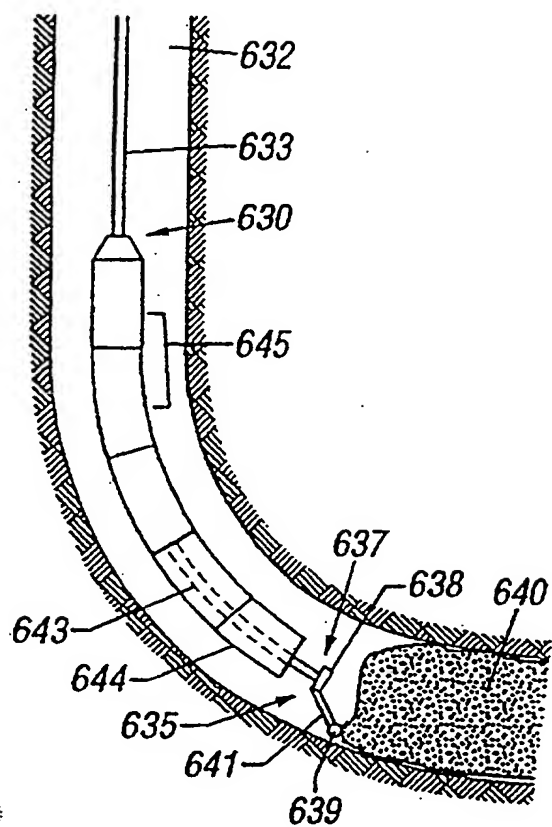


FIG. 16

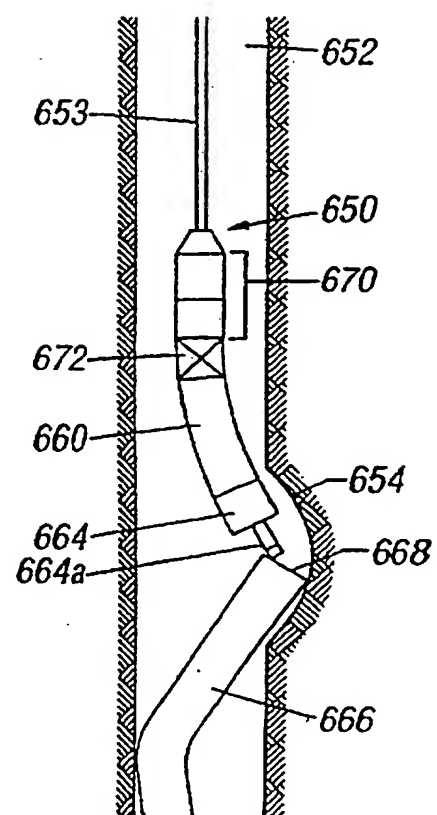
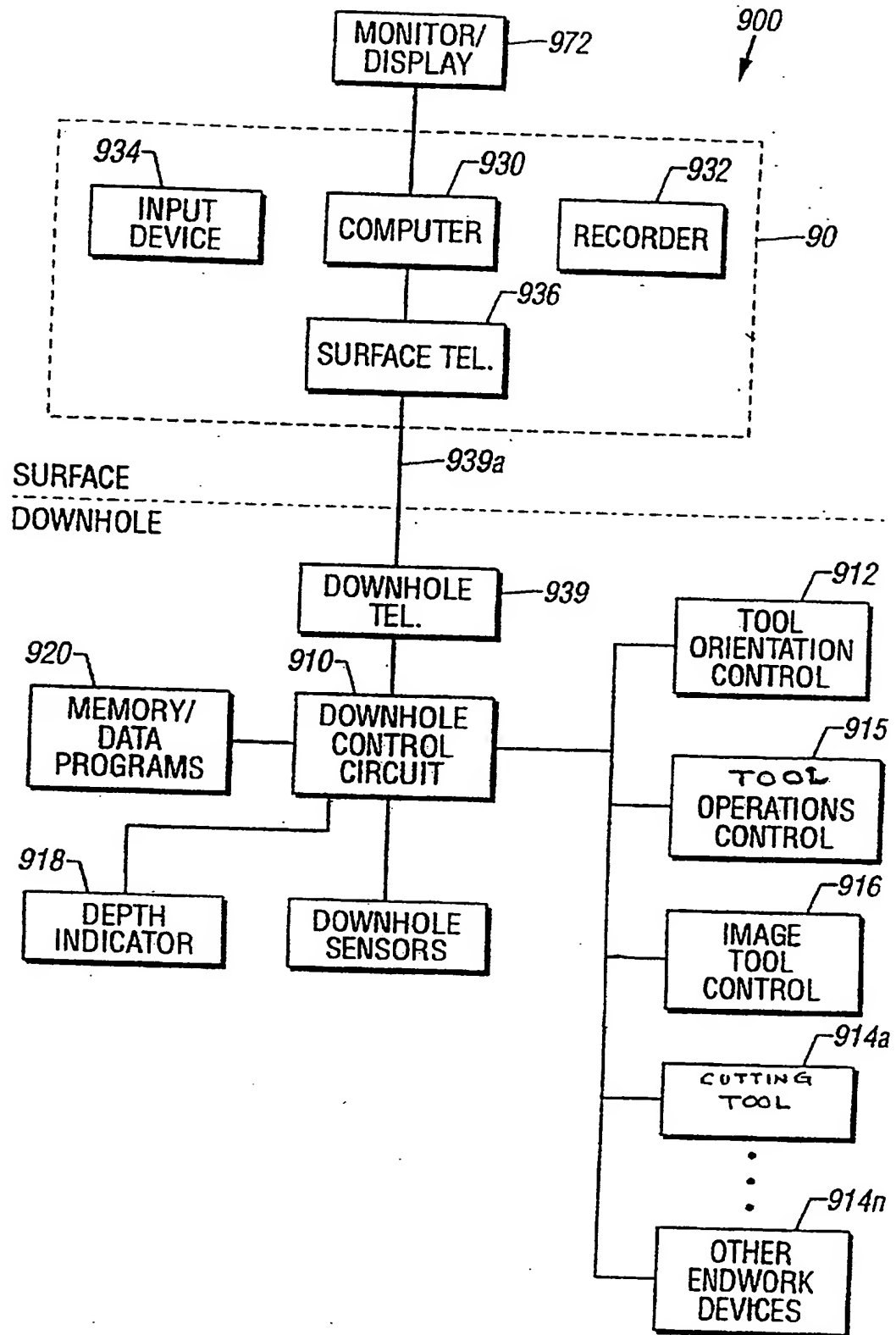


FIG. 17





PATENT APPLICATION

**TITLE:        APPARATUS AND METHOD FOR PERFORMING IMAGING AND  
DOWNHOLE OPERATIONS AT WORK SITE IN WELLBORES**

Field of the Invention

5            This invention relates generally to downhole tools for use in wellbores and more particularly to tools which can image a work site or an object in a wellbore, communicate with the surface and perform a desired end work or service at the work site, during a single trip in the wellbore. The present invention also provides novel imaging devices and end work devices and various  
10        downhole tool configurations for imaging worksites and performing the desired end works.

Background of the Invention

15            To produce hydrocarbons (oil and gas) from the earth's formations, wellbores (also referred to in industry as boreholes) are formed to desired depths. The shallow portion of the wellbore is typically large in diameter, which is lined with a metal casing to prevent caving of the wellbore. The wellbore is then drilled to a desired depth to recover hydrocarbons from the subsurface  
20        formations. After the wellbore has been drilled, a metal pipe, generally referred to in the art as the casing or pipe, is set in the wellbore by injecting cement

5 through the annulus between the casing and the wellbore. Branch or lateral wellbores are frequently drilled from a main wellbore to form deviated or horizontal wellbores for improving production of hydrocarbons from the subsurface formations.

10 A large proportion of the current drilling activity involves directional drilling, i.e., drilling deviated and horizontal wellbores, to improve the hydrocarbon production and/or to withdraw additional hydrocarbons from the earth's formations. The wellbores are then completed and put into production. The drilling and completion processes involve a number of different operations.

15 Such operations may include cutting and milling operations (including cutting relatively precise windows in the wellbore casings), sealing junctures between intersecting wellbores, welding, re-entering lateral wellbores, perforating, setting devices such as plugs, sliding sleeves, packers and sensors, remedial operations, sealing, stimulating, cleaning, testing and inspection including

20 determining the quality and integrity of a juncture, testing production from a perforated zone or a portion thereof, collecting and analyzing fluid samples, and analyzing cores.

Oilfield wellbores usually continue to produce hydrocarbons for many

25 years. Various types of operations are performed during the life of producing wellbores. Such operations include removing, installing and replacing different

5 types of devices, including fluid flow control devices, sensors, packers or seals, remedial work including sealing off zones, cementing, reaming, repairing junctures, milling and cutting, freeing stuck sleeves, diverting fluid flows, controlling production from perforated zones, setting sleeves, and testing wellbore production zones or portions thereof.

10

Typically, to perform downhole operations at a work site in a preexisting wellbore, whether during the drilling, completion, production, or servicing and maintaining the wellbore, a desired tool is conveyed downhole, positioned into the wellbore at the work site and the desired operation is performed. Most of  
15 the prior art tools are substantially mechanical tools or electro-mechanical tools. Such tools lack downhole maneuverability, in that the various elements of the tools do not have sufficient degrees of freedom of movement, lack local or downhole intelligence, do not obtain sufficient data with respect to the work site or of the operation being performed, do not provide an image of the work  
20 site during the trip made for performing the end work, and do not provide confirmation of the quality and integrity of the work performed. Such prior art tools usually require multiple trips downhole to image a work site, perform an operation and then to confirm whether the operation has been properly performed. Multiple downhole trips can be very expensive, due to the rig or  
25 production down time.

5           The present invention addresses some of the above-noted problems and provides downhole service tools (also referred to as the downhole tool or service tool) which can be positioned and oriented adjacent a desired work site, images of the work site to the surface, perform the desired work at the work site and confirm or inspects the quality of the work during a single trip into a preexisting wellbore. The present invention provides imaging devices, end work devices and various downhole tool configurations to image work sites and to perform desired operations in preexisting wellbores. The imaging devices include an optical viewing device, an inflatable imaging device, ultrasonic devices and a tactile device. The end work devices include cutting devices, reentry devices, 15. sealing devices, welding devices, testing and servicing devices.

#### **SUMMARY OF THE INVENTION**

20           The present invention provides a downhole tool for imaging a location constituting a work site of interest in a preexisting wellbore and for performing a tool operation at the work site during a single trip in the wellbore. The downhole tool includes an imaging device for imaging the work site and an end work device for performing a desired operation or an end work at the work site. The imaging device may determine the image downhole and transmit the image 25 to the surface or transmit the image data for processing at the surface. The downhole tool may be conveyed into the wellbore by any suitable method,

5 including a wireline, a tubing, and a robotics device that moves the downhole tool inside the wellbore.

Any suitable imaging device may be utilized for the purpose of this invention, including a camera for optical viewing, microwave device, contact  
10 device (tactile device) such as a probe or a rotary device, an acoustic device, ultrasonic device, infra-red device and radio frequency ("RF") device.

The end work devices may include a fishing tool to engage a fish  
downhole, whipstock, diverter, re-entry tool, packer, seal, plug, perforating tool,  
15 fluid stimulation tool, fluid fracturing tool, milling tool, cutting tool, patch tool, drilling tool, cladding tool, welding tool, deforming tool, sealing tool, cleaning tool, tool for installing a device, tool for removing a device; setting device, testing device, an inspection device, acidizing tool, an anchor, and a tool that engages with a downhole object.

20

In the downhole tools of the present invention, one or more devices are provided to position and orient the imaging device and the end work device as desired. Each downhole tool preferably includes a computer or processor and associated memory for storing therein models and programs for controlling the  
25 operations of the imaging device and the end work device. A surface computer receives the data from the downhole tool and displays the image of the work

5 site for use by an operator. A two-way telemetry system provides communication between the surface computer and the downhole tool.

The present invention also provides ultrasonic imaging devices, including a device which can image radially and downhole (in front) of the downhole tool.

10 In one mode, the ultrasonic imaging device transmits signals by sweeping a preselected frequency range to obtain an effective operating frequency. The device then continues to operate the transmitter at such effective frequency to generate data representative of the attributes of the work site.

15 The present invention also provides an imaging device for obtaining still and/or video pictures of a work site in the wellbore. This viewing device includes a camera or another suitable device for taking the pictures and a mechanism to displace the non-transparent fluid in the wellbore with a transparent fluid. This invention further provides an inflatable device for

20 providing the image of an object in the wellbore when such device is inflated and urged against the object.

The downhole tool may further include sensors for providing information about the condition of the downhole tool in the wellbore. Such sensors may

25 include sensors for determining temperature, pressure, fluid flow, pull force, gripping force, tool centerline position, tool configuration, inclination, and

5 acceleration. Formation evaluation sensors and other sensors to log the wellbore may also be included in the downhole tool of the present invention.

The present invention also provides certain end work devices, including a high pressure fluid cutting tool, which includes a source of supplying a fluid  
10 at a relatively high pressure and a cutting element for discharging the high pressure fluid. The fluid source may include serially arranged pressure stages, wherein each such stage increases the fluid pressure above its preceding stage. The fluid may be pulsed prior to supplying it to the cutting element. A control unit controls the position and orientation of the cutting element relative to the  
15 work site. The control unit may be programmed to cut according to a predetermined pattern provided to the control unit.

In each of the downhole tools of the present invention, the operation of the imaging device and the end work device may be controlled from the surface  
20 and/or by the computer or processor in the downhole tool.

Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art  
25 may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims

5      appended hereto.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment,  
10      taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, and wherein:

FIGS. 1 and 1A are schematic diagrams of a system utilizing a service tool conveyed into a wellbore for imaging a work site in the wellbore and  
15      performing a desired operation at the work site during a single trip according to one embodiment of the present invention.

FIG. 2 is a schematic diagram of a pressurized fluid cutting tool as an end work device for use in the system of FIG. 1.

20

FIG. 2A shows a manner of positioning the cutting element of the cutting tool shown in FIG. 2 in a wellbore to cut material located downhole of the cutting tool.

25      FIG. 2B-C show alternative ways to position the cutting element of the downhole cutting tool shown in FIG. 2 to cut materials located downhole of the



5 cutting tool.

FIG. 3 is an example of a predetermined profile of a section of the casing to be cut that may be stored in a memory associated with the cutting system of FIG 1.

10

FIG. 4 is a schematic diagram of the cutting tool shown in FIG. 1 with a downhole imaging device for obtaining images of areas to be cut before and after the cutting operation.

15

FIG. 5A is a schematic diagram of an embodiment of a downhole (service) tool having an ultrasonic imaging sensor for imaging a work site downhole of the service tool and an end work device for performing a desired operation at the work site during a single trip.

20

FIG. 5B is a schematic diagram of an alternative embodiment of a downhole tool having an ultrasonic imaging sensor for radially imaging a work site and an end work device for performing a desired operation at the work site during a single trip.

25

FIG. 5C is a schematic diagram of yet another embodiment of a downhole service tool having an ultrasonic imaging sensor for radially imaging a work site

5 and an end work device for performing a desired operation at the work site during a single trip.

FIG. 5D shows the downhole service tool of FIG. 5A positioned adjacent a wellbore juncture desired work site in a preexisting wellbore.

10

FIG. 6A shows a schematic diagram of an embodiment of an imaging tool for obtaining still and/or video pictures of object downhole.

FIG. 6B shows a schematic diagram of the imaging tool of FIG. 5D positioned adjacent to a juncture between a main wellbore and a branch wellbore.

15

FIG. 6C shows a schematic diagram of an inflatable imaging tool position at a wellbore juncture for determining a contour of the juncture.

20

FIG. 6D shows a configuration of the placement of sensors in the inflatable member used in the imaging tool of FIG. 5F.

FIG. 7 is a schematic diagram of an embodiment of a downhole tool having an imaging device and a milling tool disposed at a bottom end of the tool for imaging a work site and performing a milling or cutting operation at the work

25

5 site during a single trip.

FIG. 8A is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for use in lateral wellbore operations.

10

FIGS. 8B-8D are schematic diagrams of downhole tools with an imaging device and re entry device.

FIG. 9 is a schematic diagram of an embodiment of a downhole tool having an imaging device and an inflatable packer wherein the imaging device is adapted to obtain images during setting of the inflatable packer in a wellbore.

15

FIGS. 10A-10B are schematic diagrams of an embodiment of a downhole service tool having an imaging device and a welding device disposed for imaging a work site and performing a welding operation at the work site.

20

FIG. 11 is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for pressure testing the integrity of a juncture.

25

FIG. 12 is a schematic diagram of an embodiment of a downhole tool for

5 performing testing of a perforated zone.

FIG. 13 is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for performing rework operations in wellbores.

10

FIG. 14 is a schematic diagram of an alternative embodiment of a downhole tool according to the present invention for performing cementing, fracturing and squeeze-off operations in wellbores.

15 FIGS. 15-16 are schematic diagrams of embodiments of a downhole tool for performing fishing operations in wellbores.

FIG. 17 is a schematic functional block diagram relating to the general operation of the downhole imaging and servicing tools of the present invention.

20

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a schematic diagram of a system 100 for use in oilfield wellbores for imaging a work site, communicating data about the image to the surface and performing a desired operation (endwork) at the work site during a single trip in the wellbore. The system 100 includes a downhole service tool

5     200 (also referred to herein as the downhole tool or the service tool) conveyed  
from a platform 11 of a rig 12 into a wellbore 22 by a suitable conveying device  
24 from a source 66 thereof, such as a reel, being operated by a prime mover  
68. As an example, and not as any limitation, FIG. 1 shows the conveying  
device 24 to be a coiled-tubing. Other conveying methods, such as wireline or  
10     robotics devices may also be utilized. The upper end 202 of the service tool is  
connected to the tubing 24 via a suitable connector 204. During operations, a  
drilling fluid from a source thereof 60 may be supplied to the wellbore 22 by a  
pump 68.

15             A surface control unit 70 placed at a suitable location on the rig platform  
11 preferably controls the operation of the system 100. The control unit 70  
includes a suitable computer and memory for processing data, providing  
selected information to an operator on a display 72, including images of the  
work site, logs during tripping of the wellbore, location (depth) of the tool 200  
20     in the wellbore and orientation of the various elements of the service tool 200  
in the wellbore 22 and values of selected tool, formation and wellbore  
parameters. The data from the service tool 200 may be transmitted to the  
surface by a suitable data link (telemetry) and recorded by a recorder 75 for  
later use. Suitable alarms 74, coupled to the control unit 70, are selectively  
25     activated by the control unit 70 when certain operating parameters exceed their  
respective limits. The operation of control units, such as the control unit 70,

5 is known and is, thus, not described in detail herein.

The service tool 200 includes one or more imaging devices or image sensors 210 for imaging work sites downhole, one or more end work devices 212a-212b, one or more control mechanisms (hydraulic or electro-mechanical) 214 for controlling the operation of the end work devices 212a-212b and/or the imaging devices 210. The tool 200 may also include other sensors and devices, generally denoted herein by numeral 216, for determining desired parameters or characteristics relating to the tool 200 and the wellbore 22. Such sensors and devices may include devices for measuring temperature and pressure inside the tool 200 and in the wellbore 22, sensors for determining the depth of the tool in the wellbore 22, position (x, y, and z coordinates) of the tool 200, inclinometer for determining the inclination of the tool 200 in the wellbore 22, gyroscopic devices, accelerometers, devices for determining the pull force, center line position, gripping force, tool configuration and devices for determining the flow of fluids downhole.

The tool 200 further may include one or more formation evaluation tools for determining the characteristics of the formation surrounding the tool in the wellbore. Such devices may include gamma ray devices and devices for determining the formation resistivity. The tool 200 may include devices for determining the wellbore inner dimensions, such as calipers, casing collar

5 locator devices for locating the casing joints and determining and correlating tool  
200 depth in the wellbore 22, casing inspection devices for determining the  
condition of the casing, such as casing 16 for pits and fractures. The formation  
evaluation sensors, depth measuring devices, casing collar locator devices and  
the inspection devices may be used to log the wellbore while tripping into and  
10 or out of the wellbore 22.

The service tool 200 preferably includes a central electronic and data  
processing unit or downhole control unit or circuit 218 for receiving signals and  
data from downhole devices, processing such data, communicating with the  
15 surface control unit 70 and for controlling the operations of the downhole  
devices. The control unit 218 preferably includes one or more processors  
(micro-controllers or micro-processors) for performing data manipulation  
according to programmed instructions provided thereto from the surface or  
stored in memory in the downhole tool 200.

20 The service tool 200 preferably includes a two-way telemetry 220 that  
includes a transmitter for receiving data including the image data, from the  
control unit 218, downhole sensors and devices and transmits signals  
representative of such data to the surface control unit 70. Any suitable  
25 transmitter may be utilized for the purpose of this invention including an electro-  
magnetic transmitter, a fluid acoustic transmitter, a tubular fluid transmitter, a

5 mud pulse transmitter, a fiber optics device and a conductor. The telemetry system 220 also includes a receiver which receives signals transmitted from the surface control unit 70 to the tool 200. The receiver communicates such received signals to the various devices in the tool via the control unit 218 as explained later in reference to FIG. 17.

10

Still referring to FIG 1, the imaging sensor or device 210 may be any suitable sensor including a camera for optical viewing, microwave device, contact device (tactile device), such as a probe or a rotary device, an acoustic device, ultrasonic device, infra-red device, or RF device. The imaging sensor 15 210 may be a non-contacting device, such as an ultrasonic device, or a contacting device that has one or a series of projections from the tool 200 that engage with the wellbore and objects in the wellbore. If the quality or resolution of the image of the work site provided by the imaging device 210 depends, at least in part, on the frequency of the transmitted signal by the 20 imaging device 210, then it is preferred to adapt the device to sweep the frequency in a predetermined range of frequencies to determine an effective frequency and then obtain the image at such effective frequency. The imaging sensor 210 may be employed to provide a still or motion picture of a work site or an object downhole; or to determine the general shape of the object or the 25 work site or to distinguish certain features of the work site prior to, during and/or after the desired operation has been performed at the work site.



5           Still referring to FIG. 1, the end work devices 212a and 212b may include any device for performing a desired operation at the work site in the wellbore. The end work device 212a-212b may include a fishing tool adapted to grab a fish downhole, whipstock, diverter, re-entry tool, packer, seal, plug, perforating tool, fluid stimulation tool, fluid fracture tool, milling tool, cutting tool, drilling  
10 tool, workover tool, testing tool, cementing tool, welding tool, an anchor, acidizing tool or inspection tool. As noted earlier, one or more end work devices 221a-212b may be included in the tool 200 for performing the desired operations at one or more work sites in the wellbore. Use of certain of these devices with an imaging sensor is described below as examples.

15           Additionally, the service tool 200 may include downhole controllable stabilizers 219a and 219b, each such stabilizer having a plurality of independently adjustable pad segments for providing lateral movement and lateral stability to the tool 200 and for anchoring the tool 200 in the wellbore  
22. Such stabilizers are especially useful in deviated and horizontal wellbores. A plurality of independently controlled outwardly extending arms 219c may be  
20 utilized to provide lateral movement and stability to the tool 200 within the wellbore 22. For a majority of the downhole imaging and servicing applications the end work device utilized is designed for the specific application. In some applications, several end work devices may be incorporated into the service tool  
25 200. To provide desired degrees of freedom for each of the end work devices 212a-212b and the imaging device 210, such devices are coupled to the tool

5 via knuckle joints, such as joints, 212a, 212b' and 210a respectively. The movement of such knuckle joints is preferably controlled by the control unit 218. The degrees of freedom present in the tool 200 and the type of image sensor utilized preferably allow obtaining the image of any work site in the wellbore.

10

The service tool 200 is preferably modular in design, in that selected devices in the tool are individual modules that can be interconnected to each other to assemble the desired configuration of the tool 200. It is preferred to form the image device 210 and the end work devices 212a-212b as modules so that they can be placed in any order in the tool 200. Also, each of the end work devices 212a-212b and the image device 210 have independent degrees of freedom so that the tool 200 and any of the devices can be positioned, maneuvered and oriented in the wellbore in substantially any desired manner to perform the desired downhole operations.

20

The service tool 200 may be conveyed into the wellbore by a wireline, a coiled-tubing, a drill pipe, a downhole thruster or locomotive for pushing the tool 200 into a horizontal wellbore or a robotics device on the tool to move and guide the service tool in the wellbore.

25

As shown in FIG. 1A, the end work device 212' or any other device in

5 the tool 220 may have independently controlled downhole movements, such as shown by the solid lines 212' a and dotted lines 212' b, which allow the device 212' to be positioned at any angle in the wellbore 22. Thus, the service tool 200 can be positioned adjacent to a work site in a wellbore, image the work site, communicate such images online to the surface, perform the desired work  
10 at the work site, and confirm the work performed during a single trip into the wellbore.

As noted-above, the system 100 may utilize any number of different imaging devices and end work devices. A number of such tool combinations are  
15 described below. Prior to describing such tools, a novel cutting and milling device and imaging sensors are first described while referring to FIGS. 2-4.

FIG. 2 shows a schematic diagram of the system utilizing a novel high pressure fluid cutting device or tool 20 for cutting and milling materials in the  
20 wellbore 22 according to one embodiment of the present invention. In general, the cutting tool includes a cutting element such as a nozzle, for discharging a relatively high pressure fluid to cut the member. A source of supplying the high pressure fluid in the downhole tool provides the high pressure fluid to the cutting element. The cutting element may be continuously positioned and  
25 oriented at the desired location about the member to be cut by a control circuit contained in the downhole tool and/or at the surface.

5           The cutting tool 20 has a tubular housing (body) 26, which is adapted for connection with the conveying device 24 via a suitable connector 202. The housing 26 contains the various elements of the cutting tool 20, which include a cutting element section 28, a power section 34 for supplying pressurized fluid to the cutting element section 28, a control unit 36 which controls the vertical and radial position of the control element 28 and a downhole control unit 38 for  
10           housing the circuits and memories associated with the downhole tool 20.

          The bottom section 28 of the housing 26 houses a cutting element 30 that terminates in a nozzle or probe 30a suitable for discharging a relatively high  
15           pressure fluid in the form of a jet stream of a relatively small cross-sectional area. For the majority of downhole cutting or milling applications, water discharged at a pressure greater than 60,000 psi is adequate in removing materials from within a wellbore. In cutting pipes, which are more than one-half inch thick, higher pressure may be required. The section 28 preferably rotates  
20           about the joint 32, which connects the section 28 with a hydraulic power section, generally denoted herein by numeral 34.

          The power section 34 preferably includes a plurality of serial sections  $P_1$ - $P_n$ , each of which increases the pressure of a fluid above the pressure of the  
25           preceding section by a predetermined amount. The last section  $P_n$  discharges the fluid into the cutting element 30 at the desired pressure. The power section

5     34 also may contain a device 33 which pulses the fluid at a predetermined rate before it is supplied to the cutting element 30. High pressure pulsed jet stream is generally more effective in cutting materials than non-pulsed jet streams. The cutting element 30 may be a telescopic member that is moved along the tool's longitudinal axis z-z (axially) within the section 28 which enables positioning the  
10     probe 30a at the desired depth adjacent to the wellbore. In an alternative embodiment, the section 28 may be fixed while the nozzle 30 may be rotated radially about the tool longitudinal axis. The above described movements of the cutting element 30 provide multiple degrees of freedom, i.e., along the axial and radial direction thereby allowing accurate positioning of the nozzle 30 at any  
15     desired location within the wellbore.

      A section 36 contains devices for orienting the nozzle tip 30a at the desired position. The cutting element section 28 is rotated about the wellbore axis to radially position the nozzle tip 32a. The cutting element 30 is moved  
20     axially to position the nozzle tip 30a along the wellbore axis z-z. Hydraulically operated devices or electric motors are preferably utilized for performing such functions. The section 36 also preferably includes sensors for providing information about the tool inclination, nozzle position relative to the material to be cut and relative to one or more known reference points in the tool. Such  
25     sensors, however, may be placed at any other desired locations in the tool 20. In the configuration shown in FIG. 2, the cutting element 30 can cut materials

5 along the wellbore interior, which may include the casing or an area around a  
junction between the wellbore 22 (main wellbore) and a branch wellbore, as  
shown in FIG. 4. To cut the casing 23, the cutting element 30a is positioned  
at a desired location. As the tool 20 starts to cut the casing 23, it is rotated to  
circumferentially cut the pipe. If concentric casings are present, the fluid  
10 pressure may be increased accordingly to cut concentric pipes.

FIG. 2A shows a configuration of a cutting element 30' that may be  
utilized to cut materials below the cutting tool 20. In this configuration, the  
probe 30a' discharges the fluid downhole of the tool 20. Arrows A-A indicate  
15 that the cutting element 30' may be moved radially while the circular motion  
defined by arrows B-B indicates that the cutting element 30' may be moved  
along a circular path within the section 28'. The cutting element configuration  
shown in FIG. 2A is useful for performing reaming operations in a tubular  
member, such as a production tubing, which are required when interior of such  
20 tubing is lined with sediments.

To remove a permanent packer difficult to remove, it is desirable to  
remove (cut away) only the packing elements and the associated anchors, if  
any, which typically lie between a packer body and the wellbore interior. The  
25 packers and anchors typically engage the casing at areas that are relatively  
smaller than the tool body. Prior art tools typically cut through the entire

5 packer, which can take excessive time. The packers can readily be removed by  
only cutting the packing elements and any associated anchors disposed  
between the packer and the casing. In such applications, the cutting nozzle  
needs to be positioned over the packing element alone. FIGS. 2B-C show a  
configuration of the cutting element 30" whose nozzle 30a" may be placed at  
10 any desired location above a packing element within the wellbore and then  
rotated to cut through the such element below the nozzle. Arrows C-C indicate  
that the probe 30a" may be moved radially within the section 28" while circular  
path defined by arrows D-D indicate that the cutting element may be rotated  
within the wellbore. FIG. 2C shows the position of the cutting element 30"  
15 after it has been moved radially a predetermined distance. As is seen in FIG.  
2C, the nozzle tip 30a" extends beyond the section 28" which will allow the  
tool 20 to cut a material anywhere below the tool 20.

Electrical circuits and downhole power supplies for operating and  
20 controlling the operation of the cutting element 30, the power unit 34, and the  
devices and sensors placed in section 34 are preferably placed in a common  
electrical circuit section 38. Electrical connections between the electrical circuit  
section 38 and other elements are provided through suitable wires and  
connectors. The surface control unit 70 preferably controls the operation of the  
25 cutting system 10.

5           The operation of the cutting system 10 will now be described with respect to cutting a section or window in a casing while referring to FIGS. 2 and 3. The tool 20 is conveyed downhole and positioned such that the nozzle is adjacent the section to be cut. The stabilizers 40a-b are set to ensure minimal radial movement of the tool 20 in the wellbore 22. A cutting profile 80 (FIG. 10 3) defining the coordinates for the outline of the section to be cut is stored in a memory (not shown) associated with the system 10. Such memory may be in the downhole circuit 36 or in the surface control unit 70. An example of such outline is shown in FIG. 3. The arrows 82 define the vectors associated with the profile 80. The profile 80 is preferably displayed on the monitor 72 at 15 the surface. An operator orients the nozzle tip 30a at a location within the section of the casing to be cut. The desired values of the fluid pressure and the pulse rate are input into the surface control unit 70 by a suitable means. The tool 20 is then activated to generate the required pressure and the pulse rate. The fluid to the tool 20 is preferably provided from the surface via the tubing 20 24. Alternatively, the wellbore fluid may be used.

          If the section to be cut is such that it will remain in position after it has been cut, perhaps due to the presence of a cement bond, or if the cut section can be dropped to the wellbore bottom as debris, then the system 10 may be 25 set so that the nozzle tip 30a will follow the profile 80, either by manual control by the operator or due to the use of a computer model or program in the



5 system. If the section must be cut into small pieces or cutting so that they may  
be transported to the surface, the cutting element is moved within the profile  
at a predetermined speed along a predetermined pattern, such as a matrix. This  
method ensures that the casing section will be cut into pieces that are small  
enough to be transported to the surface by circulating a fluid through the  
10 wellbore. During operations, the downhole circuits contained in the section 38  
communicate with the surface control unit 70 via a two-way telemetry. The  
downhole telemetry is preferably contained in a section 39.

FIG. 4 shows the downhole cutting tool of FIG. 2 with an imaging device  
15 90 attached below the cutting section 28. Any suitable imaging device may be  
utilized. The imaging device 90 is utilized to confirm the shape of the section  
of the casing or the junction after the cutting operation has been performed.  
The imaging device 90 may also be utilized to image the area to be cut to  
generate the desired cutting profile and then to confirm the cut profile after the  
20 cutting operation. This enables the imaging of a location at a work site of  
interest and the performance of desired operation at the work site in a  
preexisting wellbore. Other types of downhole service tools may be utilized for  
imaging a location in a wellbore at which a tool operation is to be performed and  
performing the desired tool operation at the work site without retrieving the tool  
25 from the wellbore. Certain downhole end work devices are described later.

5           FIGS. 5A-5C show embodiments of downhole ultrasonic imaging devices for use with an end work device to image a work site of interest and to perform a desired operation at the work site during a single trip into the wellbore.

FIG 5A shows a downhole service tool 250 having an end work device  
10   252 for performing a desired operation downhole, an ultrasonic device 260 (ultrasonic imaging sensor) placed downhole of the end work device 252 for imaging a work site or an object in the wellbore. The imaging device 260 has a number of sensor elements 264 arranged on a body. Each sensor element 264 acts as a transmitter and receiver. The preferred frequency range is between  
15   100 KHz and 500 KHz. The ultrasonic transmitter is preferably adapted to sweep the frequency within a predetermined range of frequencies. The signals transmitted by the sensor element 264 are reflected back from the work site or the object and the reflected signals are received by the sensor elements 264, which are processed by the control unit 256 or circuit in the tool 250 and  
20   transmitted uphole via telemetry 258 to provide an image of the work site.

The ultrasonic sensor 260 may be rotated or beam steered (i.e. electrically rotating or directing) to scan the inside of the wellbore. The ultrasonic signals are transmitted at a predetermined rate and the reflected  
25   signals are received by the sensor elements 264 between successive firings of the transmitter. The end work device 252 may include a work element 253

5 that may be rotated by device 254 along the arrows 252a to orient the work  
element radially and may be moved vertically as shown by the arrows 252b,  
i.e., longitudinally to move the work element 253 uphole or downhole, which  
enables positioning the work element at any desired location in the wellbore.  
The sensor 260 and the end work device 252 are independently rotatable. The  
10 sensor 260 may be disposed above the end work device 252.

As shown in the tool 250' of FIG. 5B, the sensor elements 264' may be  
arranged on the body 255 of the end work device 252' around the end work  
element 253'. The sensor elements 264' may be disposed in any desired  
15 manner to image a segment of the wellbore or the entire wellbore interior. The  
tool may be moved along the directions denoted by arrows 252a' and 252b'.  
The vertical length of the sensor elements 264' and the spacing there between  
defines the vertical imaging sweep and the resolution. Similarly, the horizontal  
distance of the sensor elements 264' and the spacing between the sensor  
20 elements defines the radial sweep and the resolution. Alternatively, sensor  
elements may be arranged on the tool to direct signals downhole, as shown in  
FIG. 5C here the sensor elements 264" are disposed at the downhole (bottom)  
end of a service tool 250". This enables the service tool 250" to image an  
object or a work site downhole of the service tool 250".

25

FIG. 5D shows the downhole service tool 250, shown in FIG. 5A,

5 positioned adjacent to a juncture 304 between a main wellbore 300 and a branch or lateral wellbore 302. The tool 250 may be utilized to image the juncture 304 and perform an operation thereat. The tool 250 provides an image of the juncture 304 to the surface prior to performing an operation. The image may be utilized to position the tool 250 at the desired location and to  
10 appropriately orient the tool 250 adjacent the juncture 304. The desired operation may then be performed at the juncture 304, which may include a window cutting operation, reaming operation, cementing, welding, sealing or any other desired operation.

15 **FIG. 6A** shows a schematic diagram of a system 710 for obtaining still and/or video images of a wellbore interior or an object in the wellbore. The system 710 includes a downhole tool 720 that contains a camera for taking pictures of the work site and a mechanism for displacing the non-transparent fluid around the work site with a transparent or substantially transparent fluid.  
20 For convenience and ease of explanation and understanding, and not as a limitation system 710 shows only the imaging device, i.e. without any end work device.

The system 710 includes a downhole imaging tool 720 conveyed from  
25 a platform 11 of a derrick 12 into a wellbore 122 by a suitable conveying device 124, such as a tubing or wireline. The imaging tool 720 has a tubular housing

5 726, which is adapted for connection with the conveying device 724 via a  
suitable connector 719. The housing 726 contains the various elements of  
imaging tool 720. The bottom section of the housing 726 contains a camera  
section 728, which houses a retractable camera 730. The camera 730 may be  
moved within a camera housing 732 by a hydraulic means or an electric means,  
10 such as motor, generally denoted herein by numeral 734. The electrical circuits  
and downhole power supplies for operating and controlling the camera  
movements are preferably placed in a common electrical circuit section 736.  
Electrical connections between the camera section 728 and the electrical circuit  
section 736 are provided through suitable wires and connectors between the  
15 two sections. The camera 730 in its retracted position, as shown by the solid  
lines 730, may be sealed from the outside environment by closing a hatch or  
door 738. The hatch may be adapted to open outward as shown by the dotted  
line 738a or by a sliding door (not shown). In the fully retracted position, the  
camera 730 resides completely inside the housing 728 so that the hatch 738  
20 may be closed to seal the camera 730 from the outside environment.

In the fully extended position, the camera 730 extends far enough from  
the camera section 728 or any other obstruction, as shown by the dotted line  
730a, so that the camera 730 can be rotated 360 degrees and can take  
25 unobstructed pictures of its surroundings. A light source 740 attached near the  
camera provides sufficient light for the camera to obtain pictures downhole.

5 Additional light sources (not shown) may be provided on the tool body 726 to provide light in all the directions. The camera 730 may be focused downward as shown in FIG. 6A or horizontally as shown in FIG. 6B or along any other desired direction depending upon the intended application.

10 The imaging tool 720 contains a fluid injection section 744 for injecting a substantially transparent fluid (herein referred to as the clear fluid) into the wellbore. The fluid injection section 744 is preferably placed above (uphole) the camera section 728. The fluid injection section 744 includes one or more chambers, such as 746a and 746b, for storing therein the clear fluid. A pump  
15 746 in the section 744 is used to controllably inject the clear fluid from the chambers 746a-746b into the wellbore below the camera section 728 via a fluid line 748. The fluid line 748 runs from the fluid injection section 744 through the camera section 728 to an outlet point 748a below the camera section 728. Any downhole electrical control circuits and related power supplies for operating  
20 the pump 746 are preferably housed in the electrical section 736.

A surface control unit 770 placed at a suitable location on the rig platform 711 preferably controls the operation of the imaging system 710. The control unit 770 includes a suitable computer, associated memory, a recorder  
25 for recording data and a display or monitor 772. The operation of control units, such as the control unit 770, is known and is, thus, not described in detail

5     herein.

     The operation of the imaging system 710 will now be described in reference to obtaining an image of an object, such as object 750, stuck in the wellbore 722. To obtain the image of the object 750, the location of the object  
10     is first determined. A number of techniques have been utilized in the oilfield applications for determining the location of an object or work site in a wellbore. Any such technique or method may be utilized for determining the location of the object 750 for the purposes of this invention. The tool 720 is then conveyed into the wellbore 722 until the bottom end 752a of the fluid return  
15     pipe 752 is below the surface 750a of the object 750 that is to be imaged. The packer 733 is then inflated or set in the wellbore 722 to seal the wellbore section 722a below the camera section 728 from the wellbore section 722b above the packer 733. The pump 746 is then activated from the surface control unit 770 to inject the clear fluid from the chambers 746a-b into the  
20     wellbore section 722a via fluid line 748. The injection of the clear fluid into the section 722a causes the wellbore fluid present in the section 722a to enter the fluid pipe 752, which fluid is discharged into the wellbore section 722b above the packer 733 via a port 752b. This processes is continued until the wellbore fluid between the port 752a and the camera section 728 has been replaced with  
25     the clear fluid. The clear fluid chosen is preferably lighter than the wellbore fluid and will not mix with the wellbore fluid. Such a clear fluid when injected into

5 the wellbore section 722a will uniformly displace the wellbore fluid. In some applications, it may be necessary to continue to inject additional clear fluid so as to completely flush out the wellbore fluid from section 722a. The system of the present invention may employ a clear fluid source at the surface (not shown) instead of downhole chambers. In this embodiment, the clear fluid is  
10 continuously supplied to the chamber 746 from a surface source via a line placed in the conveying means 724. Such a system may be necessary when large quantities of clear fluid are required to flush out the wellbore fluid.

After the object 750 has been exposed to the clear fluid, the camera door  
15 738 is opened and the camera 730 is lowered to its fully extended position 730a. To obtain the images of the object 750, the camera lights 740 are activated, the camera 730 is oriented in a desired position and the camera is operated to obtain images of the object 750. The images from the camera are transmitted by the downhole control circuits in section 736 to the surface  
20 control unit 770 via a two-way telemetry 725. The images are displayed on the monitor 772. The operator can orient the camera in any desired direction and continue to obtain images. If a video camera is used, the motion pictures are displayed on the monitor. The images are recorded in the recorder associated with the surface control unit 770.

25

FIG. 6B shows the application of the imaging system 710 described



5     above in reference to FIG. 5D for obtaining images of a junction 760 between  
a main wellbore 722 and a branch wellbore 723. To obtain images of the  
junction 760, a packer 735 is first set in the wellbore 722 below the junction  
760 to completely seal off the wellbore section 22c lying below the packer 35.  
The imaging tool 720 is then conveyed in the wellbore 722 so that the packer  
10   33 is completely above the junction 760 while the port 752a of the fluid return  
line 752 is below the junction 760. The imaging tool 720 is operated as  
described earlier to displace the wellbore fluid in the wellbore section 722a'  
between the packers 733 and 735 with the clear fluid. The camera 730 is then  
oriented in the direction of the junction 760 to obtain the desired images.  
15   Images of other objects in the wellbore and any section of the wellbore may be  
obtained by the imaging system 710 in the above-described manner.

FIG. 6C shows another embodiment of a downhole imaging tool 800.  
The imaging tool 800 includes a flexible inflatable device 810 at a lower end  
20   of the tool 800. A fluid injection system 812 in the tool 800 injects a fluid into  
the device 810, thereby inflating the device 810. The fluid injection system  
812 preferably contains a fluid pump section 814 having a reversible pump  
therein for injecting or pumping a fluid from a chamber 816 into the device 810  
and vice versa.

25

FIG. 6D shows a cross section of the flexible inflatable device 810. It

5 includes a bladder 840 made from a flexible material, such as rubber. A plurality of sensors 842 are arranged along the inner surface 840a of the bladder 840 in a matrix or grid as shown in FIG. 6D. Each such sensor provides a signal corresponding to the deformation of the bladder surface to which the sensor is attached from a predetermined norm. The signals from each such  
10 sensor are transmitted to a downhole control circuit 816 via a conductor 844 and communication link 848. Fluid line 846 provides access to the bladder inside 840a. The downhole control circuit 816 controls the operation of the pump section 812, receives data or signals from the each of the sensors 842, conditions the signals and may manipulate the signals to obtain an image. The  
15 downhole control circuit 816 may transmit the conditioned signals to a surface control unit, such as unit 970 shown in FIG. 17, which produces the image based on a model stored in the control unit. The model is predetermined or predefined based on the geometry of the flexible member 810 and the configuration of the sensors 842. The model is stored in a downhole memory  
20 associated with the downhole control circuit 816 when the system is designed to compute the model downhole.

Operation of the tool 800 will now be described in the context of obtaining an image of a junction between the main wellbore 822 and the branch  
25 wellbore 823. To obtain an image of the junction 860, the tool 800 is conveyed into the main wellbore 822 until the flexible member is adjacent to the

5 junction 860. The fluid from the fluid section 812 is then injected into the flexible member 810, thereby inflating the member 810. A portion of the flexible member at the junction 860 attains the shape that corresponds to the junction 860 outline. The downhole control circuit 816 measures the signals from each of the sensors 842 and processes such signals as described above  
10 to obtain the image of the junction. Image of an object in the wellbore, such as object 850 shown in FIG. 6B, is obtained by inflating the flexible member 810 while urging it against the object.

FIGS. 7 - 16 show embodiments of certain downhole tools which are  
15 adapted to image a work site of interest and perform a desired operation at work sites in a pre-existing wellbores during a single trip according to the present invention.

FIG. 7 shows an embodiment of a downhole service tool 350 conveyable  
20 by a tubular member 356, such as a drill pipe. The end work device 352 is a milling device and is disposed at the bottom end of the conveying member 356. A suitable imaging device 354 is disposed above the milling device 352. A conduit 358 may be utilized to supply hydraulic or electric power to the tool 350. A control unit, other sensors, and associated electronic circuitry and  
25 telemetry may be disposed in the tool 350 as described earlier. During operation, the work site or the object to be milled is imaged by the imaging

5     sensor 354 and the cutting operation is performed by the milling device 352.  
Images of the area being cut are periodically obtained to ensure that the cutting  
operation is being performed correctly. Other end work devices, such as tools  
for determining the widow seal integrity may be disposed with the milling device  
352.

10

FIG. 8A shows a downhole service tool 370 that may be utilized to image  
a location in the wellbore 375 and then drill the lateral wellbore 377 and/or to  
facilitate re-entry of an end work device into the lateral wellbore 377. To drill  
the lateral wellbore 377, the tool 370 is positioned above a whipstock or any  
15     other suitable re-entry device 379. An image device 380 provides images of the  
location where the lateral wellbore 377 will be drilled, which image may be  
utilized to position and orient the drilling element (bit) 372. Alternatively, since  
the image is available, the operator can set kick-off devices 382 to cause the  
device 372 to perform an operation at a juncture 377a without first requiring  
20     the installation of the re-entry device 379, thereby avoiding another trip  
downhole. The tool 370 may similarly be used to reenter the wellbore 377 to  
perform secondary operations in the branch wellbore 377, thereby eliminating  
an extra trip to install the re-entry device 379.

25

FIGS. 8B and 8C show another embodiment of a downhole service tool  
385 which can be utilized to enter a branch wellbore 377 from a main wellbore

5 375 without the use of a re-entry device, such as a whipstock or a diverter. The downhole service tool 385 includes an end work device 386 at the service tool 385 downhole end, a suitable imaging device 387 and a downhole operated tool orientation device 388. The device 388 preferably is a hydraulically or electrically operated knuckle-type joint which bends the tool 385  
10 portions above and below the device 388 up to a predetermined maximum angle. The service tool 388 is lowered into the main wellbore 375 to a known distance above the juncture 377a. The image device 387 provides images of the juncture 377a. The operator then orients the tool 385 and activates the device 388 to bend the tool 385 at a predetermined angle. The device is locked  
15 into the bent position and the tool 385 continues to be lowered into the wellbore. Inserting the tool 385 further causes it to enter into the branch wellbore 377 as shown in FIG. 8C.

Once the bottom end device 386 has entered into the branch wellbore  
20 377, the device 388 is unlocked, which allows the front portion of the tool 385 to straighten as it moves further into the branch wellbore 377. After the tool 385 has been conveyed to the desired work site in the branch wellbore 377, the end work device 386 is then utilized to perform the desired operation. Thus, the service tool configuration of FIGS. 8B-8C allows the operator to (a) convey  
25 the service tool 385 into a branch or lateral wellbore 377 without the use of a secondary device, such as a diverter, and (b) image a desired work site in the

5     branch wellbore and perform a desired operation at the work site in a single trip.  
This service tool 385 can eliminate two downhole trips, one to install a diverter,  
such as the diverter 379 shown in FIG. 8 and a second trip to image the work  
site prior to performing the work at the work site.

10           FIG. 8D shows an alternative device 390 for causing the service tool 385  
to enter the branch wellbore without the use of a diverter. The device 390  
includes a plurality of arms or members which can be independently extended  
outward from the service tool body to urge against the wellbore wall 375a.  
Selectively urging the members 392 against the wellbore wall 375a causes the  
15     tool to enter the branch wellbore 377.

The knuckle-joint 388 shown in FIG. 8B and the arm members 392  
shown in FIG. 8D are operated by their respective control units in the service  
tool 385. The downhole control unit (FIG. 1) controls the operation of these  
20     devices based on instructions provided from the surface control unit 70 or  
downhole stored programmed instructions. The service tool may also be  
programmed to locate the juncture 377a and cause the tool 385 to enter the  
branch wellbore 377. Thus, the service tool shown in FIGS. 8B-8C can locate  
a lateral or multilateral juncture, adjust or orient itself and penetrate the lateral  
25     wellbore without the use of additional devices, such as diverters and  
whipstocks, and thereafter perform an end work in the lateral wellbore during

5 a single trip downhole.

FIG. 9 shows an embodiment of a service tool 400 with an imaging device 420 and a packer 410 as the end work device. The service tool 400 is shown conveyed by a tubular 402 into an open hole 404. The packer 410 has  
10 an inflatable packer element 412, which when inflated seals an annulus between the packer 410 and the wellbore 404. The packer 410 is attached to the tubular 402 by a shear bolt 406 having a weak point 406a that may be sheared to separate the packer 410 from the tubular 402. An imaging device  
420 for imaging the annulus 407 between the packer 410 and the wellbore 404  
15 is placed above the shear point 406a.

To set the packer element 412 in the annulus 407, the tool 400 is positioned in the wellbore 404 so that the packer 410 is across from the area 407. The packer 410 is set by injecting a hardening fluid, such as cement,  
20 epoxy, or another suitable material, into the packer element 412. If an acoustic device is used as the imaging device, its response characteristics are a function of the manner the annulus is being enclosed with the hardening material. The data from the imaging device 420 is analyzed to determine the quality of the bond between the packer element 412 and the formation 404. Based on the  
25 imaging characteristics, the amount of the hardening material being supplied to the packer element 412 can be adjusted to improve the integrity of the seal.

5     After the packer 410 has been set, the bolt 406 is sheared to retrieve the service tool 400 from the wellbore 404.

FIGS. 10A and 10B show examples of embodiments of downhole service tools for imaging a work site of interest and performing welding operations at the work site during a single trip in the wellbore. FIG. 10A shows the service tool 450 for welding a juncture 434 between a casing 430 in a main wellbore 435 and a casing 432 in a branch or lateral wellbore 437. The service tool 450 includes a welding device 452 at its bottomhole end. The service tool 450 may also include a milling device 456 to dress or smooth any rough welding performed by the welding device 452. An image device 458 is preferably placed above the welding device 452 and the milling device 456. The welding device 452 is coupled in the tool 450 with a rotatable joint 453. Similarly, if a milling device 456 is utilized, it is preferably disposed in the service tool 450 via rotatable joints 455a and 455b. The rotatable joints 453, and 455a and 455b allow the welding device 452 and the milling device 456 to independently rotate in the wellbore 435. The service tool 450 also includes a control unit 461 to position and orient the tool 450 in the casing 430 and other desired devices 462. A central processor 460 processes signals and data from the downhole devices and communicates with the surface computer 70 (FIG. 1) via a two-way telemetry 464.



5           To weld the casings 430 and 432 at the juncture 434, the service tool  
450 is conveyed into the casing 430 by a suitable conveying system 451. The  
imaging device 456 provides an image of the juncture 434 to the surface  
control unit 70 (FIG. 1). The welding device 452 is positioned adjacent to the  
10           junction 434. The welding tip or probe 454, having its own degrees of  
freedom, is positioned at the juncture to perform the welding operation. The  
probe 454 may be extended radially and/or axially to position the probe 454 at  
any desired location in the casing 430. The axial movement of the service tool  
450, rotary movement of the joint 453 and the axial and radial movements of  
the probe 454 provide necessary degrees of freedom of movement to position  
15           the welding probe 454 at any desired spot in the casing 430. One or more  
downhole-controlled and independently-operated stabilizers or radially  
extendable arms 466 or any other suitable device may be utilized to urge the  
probe 454 against the juncture 434 to be welded.

20           The image device 456 may be utilized to image the juncture 434 after  
welding operations or intermittently during welding operations to ensure quality  
and integrity of the welds 434a. The tool 450 may then be repositioned to  
place the milling device 456 adjacent to the weld 434a. The milling device 456  
has a milling surface 456a on its outside, which is extended outwardly and  
25           urged against the weld 434a to smooth out the weld 434a. Any suitable milling  
device, including any commercially available mechanical milling device may be

5     utilized in the service tool 450.

FIG. 10B shows a manner of utilizing the service tool 450 for welding a device 470, such as a permanent packer, a plug, or a plate below the plate inside a casing 475. To weld the device 470 inside the casing 475, the service tool 450 is placed above the device 470 to image the work site 471 to be welded. The tool 450 is then repositioned to place the welding probe 454 against the area 471. The welding operation is then performed in the manner described above. It should be noted that only one type of welding device has been described above to perform selected welding operations to describe the concept of the invention. Any other suitable welding device may be utilized with the service tool 450 to perform any type of welding operations.

FIGS. 11 and 12 show a service tool 500 for performing testing operations in the wellbore. FIG. 11 shows a configuration for testing the integrity of a seal. In the example of FIG. 11, a seal 514 is placed in a lateral wellbore 512 formed from a main wellbore 510. The service tool 500 is shown conveyed into the main wellbore 510. It includes a suitable imaging device 502, a device 504 for discharging a high pressure fluid into the wellbore 510 and a pair of packers 506a and 506b spaced apart on the service tool 500 to seal a zone of interest 518 in the wellbore 510. To test the integrity of the seal 514, the service tool 500 is positioned adjacent to a juncture 515 to provide an

5 image of the juncture 515, which image is utilized to position the tool 500 such  
that the upper packer 506a is above the juncture 515 and the lower packer  
506b is below the juncture 515. The packers 506a-506b are then set as  
shown in FIG. 11 to seal the space 518 enclosed by the seal 514, the upper  
packer 506a and the lower packer 506b. Pressurized fluid is then discharged  
10 from the device 504 into the space 518 via openings 504a. The pressure drop,  
if any, in the space 518 is measured over a predetermined time period, which  
provides an indication of the seal integrity.

FIG. 12 shows a configuration of a service tool 520 for use in testing a  
15 production zone or reservoir 525. This configuration is substantially similar to  
the tool configuration shown in FIG. 11. FIG. 12 shows a cased hole 540  
having a production zone 539. The casing 530 has a plurality of perforations  
532 through which fluids from the reservoir 525 enter into the casing 530 at  
zone 539. Periodic testing of production zones is commonly performed during  
20 the life of such production zones to determine the fluid flow from each zone or  
a portion thereof, to build and update reservoir models and to estimate the  
future production from such reservoirs. To test a production zone, such as zone  
539, the tool 520 images the perforated zone 542 (work site). The image is  
utilized, among other things, to position the tool 520 adjacent to the  
25 perforations 532. The packers 526a and 526b are set in the casing 530 to seal  
the zone 539 between the packers 526a-526b. A testing device 524 is then

5     utilized to perform desired testing. The testing device 524 shown has a flow  
control valve 524a to control the fluid flow from the reservoir into the tool 530.  
The received fluid may be collected in chambers 527 for further analysis or  
discharged into the wellbore uphole of the upper packer 526a. The testing  
device 524 also may include temperature sensors, pressure sensors and may  
10   include devices to determine chemical and/or physical properties of the fluids,  
including specific gravity, oil, gas and water content in the formation fluid. To  
determine pressure and temperature build up, commonly performed for reservoir  
modeling, the valve 524 is closed and required measurements are made over a  
predetermined time period. Any other type of testing device may also be  
15   employed in addition to or as an alternative to the device 424. The image  
obtained of the perforated zone 539 allows an operator to position the tool 530  
precisely adjacent to the desired perforations 532. The packers 526a and 526b  
may be made slidable over the tool 530 so that the length of the zone 539 may  
be adjusted downhole.

20

It will be obvious that FIGS. 11 and 12 show specific examples in which  
the service tool of the present invention can be utilized to image a work site in  
a wellbore and then perform testing (end work) during a single trip in the  
wellbore. Any other suitable testing device may be utilized for the purposes of  
25   this invention.

5           FIGS. 13 and 14 show examples of the service tool of the present invention for performing remedial work in preexisting wellbores. FIG. 13 shows the service tool 550 conveyed in a cased wellbore 555 lined with a casing 556. The casing 556 has a plurality of perforations 558 adjacent to a reservoir 560. The service tool 550 includes a suitable image device 564 and a device or unit 10 566 for injecting fluids under pressure into the wellbore 555. The remedial work in the wellbore 555 may include injecting a fluid (water, sand, glass, chemicals or mixture of water and additives, etc.) under pressure through the perforations 558 to increase the flow of formation fluids from the reservoir 560 into the wellbore 555. To perform such a remedial work, the service tool 550 15 is positioned in the wellbore 555 to obtain images of the perforated zone 568. The images are utilized to reposition the tool, if necessary. Packers 570a and 570b are set in place to isolate the desired zone of interest or the work site 568. The desired fluid is then injected into the zone 568 by the device 566 via control valves 566a. The desired fluid may be injected via tubing 557 from the 20 surface. The flow from each of the control valves 566a is preferably independently controlled by a downhole control unit 571. The above-described system is equally applicable for open hole fracturing applications.

          The service tool 550 shown in FIG. 13 may also contain a test device, 25 such as the test device 572, similar to the test device 534 shown in FIG. 11 to perform testing of the zone 568 to determine the effectiveness of the work

5 performed. The service tool 550 shown in FIG. 13 thus may be utilized to image a work site (production zone 568), perform a work (remedial work) at the work site, and then determine the effectiveness of the work performed during a single trip in the wellbore.

10 During the life of a wellbore, it is sometimes desired or even required to seal off a production zone or a portion thereof for reasons such as the zone is producing excessive amounts of water and is impeding the flow of hydrocarbons from other production zones in the same wellbore. FIG. 14 shows a configuration of a service tool 580 of the present invention for sealing  
15 a production zone 599 or a portion thereof by cementing the zone 599 and then confirming the integrity of the seal. FIG. 14 shows a service tool 580 conveyed in a cased wellbore 581 lined with a casing 582. The casing 582 has a plurality of perforations 584 adjacent to a reservoir 585. The service tool 580 includes a suitable image device 586 and a device or unit 588 for injecting cement slurry  
20 under pressure into the wellbore 581. The remedial work in the wellbore 581 may include closing off a single perforation 584a or the zone 599 having a number of perforations 584. To close off the zone 599, the tool 580 is positioned in the wellbore 581 to obtain images of the perforated zone 599. The images are utilized to reposition the tool 580, if necessary, and packers  
25 596a and 596b are set in place to isolate the desired zone of interest or the work site of interest 599. The cement is then injected from the cement device

5     588 into the zone 599 via a control valve 592b to seal the intended zone 599.  
The tool 580 is then retrieved. To cement a single perforation, such as  
perforation 584a, a flexible cup 590 on the outside of the tool 580 is urged  
against the perforation 584a. Cement or any other desired fluid is then  
controllably discharged from an opening 592a to close the perforation 584a.  
10    The tool 580 may also include a testing device 594 to test the integrity of  
cementing work. The device 594 may be a flow measuring device to determine  
if any fluid is flowing out of the cemented zone. Pressure and temperature  
measuring devices and resistivity measuring devices may also be utilized as test  
devices. Additionally, the image device 586 may be utilized to obtain secondary  
15    images of the cemented work site to determine the effectiveness of the work  
performed. It should be noted that the term cement is used to generally mean  
hardening materials, including cement slurry, epoxies and any other suitable  
material. In some cases, it is desirable to intentionally damage a formation or  
zone to seal unwanted production of formation fluids. The above-described  
20    method may also be utilized for such applications.

FIGS. 15 and 16 show examples of service tools of the present invention  
for performing fishing operations preexisting wellbores. FIG. 15 shows a  
service tool 630 conveyed in a wellbore 632 by a tubing 633. The service tool  
25    630 includes a suitable image device 635 having a retractable tactile sensor for  
imaging an object, such as a fish 640 stuck in the wellbore 632. The tactile

5 image device 635 includes a retractable probe 637, which has a tip 639 that  
can scan the entire inside of the wellbore 632. The probe tip 639 attached to  
an arm 641 which can move radially and axially around a rotary joint 638. The  
joint 638 can move axially as shown by the dotted lines 643, thereby providing  
sufficient numbers of degrees of freedom to the probe tip 639 to scan the  
10 wellbore 632. The service tool 630 includes a suitable fishing device for  
engaging the fish 640 and other devices, sensors, control circuits and telemetry,  
collectively designated by numeral 645. To retrieve the fish 640 from the  
wellbore 632, the service tool 630 is positioned above the fish 640. The  
imaging device 635 senses the location and profile of the fish 640, which is  
15 communicated to the surface. The tool 630 is then repositioned, the fishing  
device 644 is activated to engage the fish 640. Any other suitable imaging  
device may be utilized for imaging the fish 640. Also any suitable fishing device  
may be utilized for the purpose of this invention. For example, the fishing  
device may be the type that grabs the fish from the outside or the inside of the  
20 fish 640. It may be a spear type or an over-shot type device as described in  
U.S. Patent No. 5,242,201, which is incorporated herein by reference. The  
fishing tool 635 may drill into the fish 640 to securely engage the fish 640.  
The fish 640 is retrieved by retrieving the tool 630. It should be obvious that  
the tactile imaging device 635 may include more than one probes and that such  
25 imaging devices may be utilized in any of the service tools made according to  
this invention.



5           FIG. 16 shows the use of a service tool 650 conveyed in a wellbore 652  
by a tubing 653. The service tool 650 includes a suitable imaging device 660,  
including an ultrasonic and tactile device. In the example of FIG. 16 a fish 666  
is shown stuck in a wash-out area 654 of the wellbore 652. To retrieve the  
fish 666, the tool 650 is positioned adjacent to the fish 666 to image the 666  
10. fish by the imaging device 660. The tool 650 may include a one or more  
knuckle devices 672 that can be activated from the surface or downhole control  
circuits 670 to position the image device 660 and a fishing device 664 in the  
wash-out region 654. After the image is taken, the fishing device 664 is  
repositioned to engage the fish 666. The fish 666 may be moved from the  
15. wash-out region 654 by reactivating the knuckle joints 672. The fish 666 is  
retrieved by retrieving the tool 650. It should be noted that any suitable  
imaging and fishing devices may be utilized for the purpose of this application.  
The fishing tools of this invention preferably have degrees of freedom of  
movement that are sufficient to position the tool to retrieve the fish at any place  
20 in the wellbore.

Thus far selected examples of the downhole service tool have been  
described above to illustrate the concepts of the present invention. It will,  
however, be understood that many other end work devices and imaging devices  
25 can be utilized to image an object and work site in a wellbore and to perform a  
desired operation at the work site without requiring retrieving the service tool

5 according to the concepts of this invention. For example, the service tool 200 (FIG. 1) of the present invention may be utilized to locate a weak point in the well casing, such as a crack or a pit, and perform welding. The service tool 200 may be utilized to perform swaging operations downhole or to inject polymers into the wellbore. Yet, in certain other applications, it is desirable to confirm  
10 the engagement of a tool conveyed from the surface to downhole device prior to performing an operation with such tool. The service tool of the present invention may include an engagement device and a sensor for generating signals that differ when the tool is engaged with the downhole device and when it fully or properly engaged. The service tool may include without limitation any  
15 desired engagement device, including a collet type device, a screw type device, a latching device that is designed to latch into or onto a receptacle associated with the downhole device, a cone type device, a device that is designed to mate with a matching profile in the downhole device, or a collet or a pressure activated device. To perform the desired operation, the service tool is placed  
20 at a desired location in the wellbore and the sensor is activated to provide the tool response. The tool is engaged with the downhole device. The sensor continues to provide signals responsive to the engagement process. The response signature is utilized to confirm the engagement of the tool device with the downhole device.

25

Additionally, the service tool 200 may incorporate one or more robotics

5 devices that can remove a member or a sensor, install a sensor or a device,  
such as a fluid control valve, remove a liner, interchange parts, replace power  
sources, such as batteries, turbines, etc., inflate a device, manipulate a device  
or part downhole from its current position to a new position, such as a sliding  
sleeve from an open position to a closed position or vice versa, and perform any  
10 other desired function. The image device in the service tool is preferably utilized  
to locate the part to be replaced, installed or manipulated.

It is often desirable to measure selected wellbore and formation  
parameters either prior to or after performing an end work. Frequently, such  
15 information is obtained by logging the wellbore prior to performing the end  
work, which typically requires an extra trip downhole. The service tool of the  
present invention, such as tool 200 shown in FIG. 1 and other tools shown in  
FIGS. 2-16 may include one or more logging devices or sensors. For example,  
for the work to be performed in cased holes, such as shown in FIGS. 10a-14,  
20 a collar locator may be incorporated in the service tool 200 to log the depth of  
the tool 200 while tripping downhole. Collar locators provide relatively precise  
measurements of the wellbore depth and can be utilized to correlate depth  
measurement made from surface instruments, such as wheel type devices. The  
collar locator depth measurements can be utilized to position and locate the  
25 imaging and end work devices of the tool 200 in the wellbore. Also, casing  
inspection devices, such as eddy current devices or magnetic devices may be

5 utilized to determine the condition of the casing, such as pits and cracks. Similarly, a device to determine the cement bond between the casing and the formation may be incorporated to obtain a cement bond log during tripping downhole. Information about the cement bond quality and the casing condition are especially useful for wellbores which have been in production for a relatively  
10 long time period or wells which produce high amounts of sour crude oil or gas. Additionally, resistivity measurement devices may be utilized to determine the presence of water in the wellbore or to obtain a log of the formation resistivity. Similarly gamma ray devices may be utilized measure background radiation. Other formation evaluation sensors may also be utilized to provide  
15 corresponding logs while tripping into or out of the wellbore.

The description thus far substantially relates to a service tool which utilizes an image sensor and an end work device to image a work site in a wellbore and perform a selected end work. As described earlier, the service tool  
20 of the present invention also provides confirmation about the quality and effectiveness of the end work performed downhole during the same trip. The general operation of the above-described tools is described by way of an example of a functional block diagram for use with the system of FIG. 1. Such methods and operations are equally applicable to the other downhole service  
25 tools made according to the present invention. Such operations will now be described while referring to FIG. 17.

5           The downhole section of the control circuit 900 preferably includes a  
microprocessor-based downhole control circuit 910. The control circuit 910  
determines the position and orientation of the tool as shown in box 912. A  
circuit 915 controls the operation of the downhole tool. The control circuit 910  
also controls the end work devices, such as cutting tool 914a and any other end  
10 work devices, generally designated herein by numeral 914n. During operations,  
the control circuit 910 receives information from other downhole devices and  
sensors, such as a depth indicator 918 and orientation devices, such as  
accelerometers and gyroscopes. The control unit 900 communicates with the  
surface control unit 970 via the downhole telemetry 939 and via a data or  
15 communication link 939a. The control circuit 910 also preferably controls the  
operation of the downhole devices, such as the power unit 934, stabilizers and  
other desired downhole devices (not shown). The downhole control circuit 910  
includes a memory 920 for storing therein data and programmed instructions.  
The surface control unit 970 preferably includes a computer 930, which  
20 manipulates data, a recorder 932 for recording images and other data and an  
input device 934, such as a keyboard or a touch screen for inputting  
instructions and for displaying information on the monitor 972. The surface  
control unit 970 and the downhole tool communicate with each other via a  
suitable two-way telemetry system.

25

While the foregoing disclosure is directed to the preferred embodiments

5 of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

1     CLAIMS

2  
3     1.    A downhole service tool, comprising:

4           (a)   a packer adjacent a lower end of the tool,  
5                said packer having a packing member on a  
6                housing that forms a seal between the  
7                housing and a work site in a pre-existing  
8                wellbore when a fluid is injected into the  
9                packing member; and

10          (b)   a sensor uphole of the packer for providing  
11                data representative of an image of the work  
12                site when the downhole tool is conveyed  
13                into the wellbore for setting the packer in  
14                the wellbore.

15  
16     2.    A downhole service tool substantially as  
17            hereinbefore described with reference to the  
18            accompanying drawings.

19  
20     3.    A downhole tool for imaging a work site within a  
21            pre-existing wellbore and performing a tool  
22            operation at the work site during a single trip  
23            of the tool in the wellbore, the tool  
24            comprising:

25           (a)   an imaging device in the downhole tool for  
26                imaging the work site; and

27           (b)   a work device in the downhole tool for  
28                performing the tool operation at the work  
29                site, whereby the downhole tool obtains the  
30                image of the work site and performs the  
31                tool operation at the work site during a

1           single trip of the downhole tool into the  
2           wellbore.

3

4       4.    The downhole tool of claim 3, wherein the  
5           imaging device is selected from the group  
6           comprising a camera for optical viewing, an  
7           acoustic device, an ultrasonic device, an infra-  
8           red device, an RF device, a microwave device, a  
9           contacting device, a tactile device and a fibre  
10          optic device.

11

12       5.    The downhole tool of claim 3, wherein the  
13          wellbore is a cased wellbore.

14

15       6.    The downhole tool of claim 3, wherein the  
16          imaging device is a contacting device comprising  
17          a series of projections extending from the  
18          downhole tool that can engage with the wellbore  
19          and objects in the wellbore.

20

21       7.    The downhole tool of claim 3, wherein the  
22          transmitter is selected from the group  
23          comprising an electromagnetic transmitter, a  
24          fluid acoustic transmitter, a tubular fluid  
25          transmitter, a mud-pulse transmitter, a fibre  
26          optics transmitter and a conductor wire  
27          transmitter.

28

29       8.    The downhole tool of claim 3, wherein the end  
30          work device is selected from the group  
31          comprising a fishing tool to engage with a fish



1 downhole, a whipstock, a diverter, a re-entry  
2 tool, an anchor, a packer, a seal, an inflatable  
3 packer, a plug, a perforating tool, a fluid  
4 stimulation tool, an acidizing tool, a fluid  
5 fracturing tool, a milling tool, a cutting tool,  
6 a patch tool, a drilling tool, a cladding tool,  
7 a welding tool, a deforming tool, a sealing  
8 tool, a cleaning tool, a device for installing a  
9 device in the wellbore; a device for removing a  
10 device downhole; a testing device for performing  
11 a test in the wellbore; an inspection device;  
12 and a tool for engaging with a downhole object  
13 to perform a desired operation.  
14

15 9. The downhole tool of claim 3 further comprising  
16 a computer having at least one processor for  
17 controlling the operation of the end work  
18 device.  
19

20 10. The downhole tool of claim 3, wherein the end  
21 work device is movable radially and  
22 longitudinally relative to the wellbore.  
23

24 11. The downhole tool of claim 3 further comprising  
25 a memory positioned for recording data from the  
26 sensor for data retrieval when the service tool  
27 is brought back to the surface.  
28

29 12. The downhole tool of claim 3 further comprising  
30 a memory pre-programmed with a work site data  
31 model for correlating data generated downhole

1           with pre-programmed work site data to facilitate  
2           the identification of the work site.  
3  
4       13.   The downhole tool of claim 12, wherein the  
5           transmitter generates signals for transmission  
6           to the surface representative of the data  
7           correlation and, thus, of the work site data  
8           generated downhole.  
9  
10       14.   The oilfield tool of claim 13, wherein the  
11           transmitter communicates with other equipment  
12           positioned downhole in the wellbore.  
13  
14       15.   The downhole tool of claim 3 further comprising  
15           a receiver associated with the downhole tool for  
16           receiving signals sent from the surface to the  
17           downhole tool, with the receiver communicating  
18           with a processor in the downhole tool.  
19  
20       16.   The downhole tool of claim 3 further comprising  
21           a formation evaluation sensor adjacent the lower  
22           end of the tubing.  
23  
24       17.   The downhole tool of claim 3 further comprising  
25           at least one sensor for determining an operating  
26           condition of the downhole tool during drilling  
27           of the wellbore, said at least one sensor  
28           selected from the group comprising temperature,  
29           pressure, fluid flow, tool orientation, pull  
30           force, gripping force, tool centerline position,

1           tool configuration, inclination, and  
2           acceleration.  
3  
4       18.   The downhole tool of claim 3, wherein the  
5           imaging device detects objects positioned  
6           downhole of the tool.  
7  
8       19.   The downhole tool of claim 3, wherein the  
9           imaging device is an ultrasonic device  
10          positioned in the downhole tool to provide  
11          images of the work site located downhole of the  
12          downhole tool.  
13  
14       20.   The downhole tool of claim 19, wherein the  
15           ultrasonic device includes at least one  
16           transmitter for transmitting signals to the work  
17           site downhole of the downhole tool and a  
18           receiver for receiving signals reflected by the  
19           work site.  
20  
21       21.   The downhole service tool of claim 20, wherein  
22           the imaging device operates the transmitter by  
23           sweeping a preselected frequency range to obtain  
24           an effective operating frequency and continues  
25           to operate the transmitter at such effective  
26           frequency to generate data representative of  
27           attributes of the work site.  
28  
29       22.   The downhole tool of claim 3, wherein the  
30           imaging device is beam steered to generate data

1           representative of the properties of the work  
2           site.  
3  
4       23.   The downhole tool of claim 3, wherein the  
5           imaging device includes a sensor that is rotated  
6           to generate data representative of the  
7           properties of the work site.  
8  
9       24.   The downhole tool of claim 3, wherein the end  
10          work device is a cutting device that performs  
11          cutting with a high pressure fluid.  
12  
13       25.   The downhole tool of claim 3, wherein the end  
14          work device is a re-entry device that includes  
15          an orienting device that can be oriented to  
16          enter into a lateral wellbore intersecting the  
17          wellbore.  
18  
19       26.   The downhole tool of claim 25, wherein the  
20          orienting device is selected from a group of  
21          devices consisting of a knuckle joint, a  
22          flexible joint that is operated by a control  
23          circuit in the downhole tool, a flexible joint  
24          that is remotely operable, and a deflection  
25          device that reorients the downhole when said  
26          deflection device is urged against the wellbore.  
27  
28       27.   The downhole tool of claim 3 further comprising  
29          two spaced apart isolators, said isolators  
30          isolating a zone of interest in the wellbore.  
31

- 1     28.   The downhole tool of claim 27 further comprising  
2           a device for injecting fluid enterpriser into  
3           the zone of interest to perform testing of the  
4           zone of interest.  
5
- 6     29.   The downhole tool of claim 27, wherein the  
7           isolated zone is selected from the group  
8           consisting of a perforated zone, and juncture  
9           between the wellbore and a lateral wellbore.  
10
- 11    30.   The downhole tool of claim 3, wherein the  
12          imaging device is a tactile device having at  
13          least one probe that extends from the downhole  
14          tool to make contact with the work site to  
15          provide signals representative of the physical  
16          attributes of the work site.  
17
- 18    31.   A method of imaging a location constituting a  
19          work site of interest at which a tool operation  
20          is to be performed in a pre-existing wellbore  
21          and performing a work at the work site during a  
22          single trip, comprising:  
23          (a)   providing a tubing extending from the  
24                surface down into the wellbore, a sensor  
25                adjacent the lower end of the tubing for  
26                sensing properties associated with the work  
27                site and generating data representative of  
28                the work site, a transmitter for receiving  
29                the data and transmitting signals  
30                representative of the data to the surface  
31                and an end work device adjacent the lower

1           end of the tubing for performing the  
2           desired tool operation;  
3       (b) extending the tubing into the wellbore  
4           toward the work site;  
5       (c) sensing properties associated with the work  
6           site downhole;  
7       (d) generating data representative of the image  
8           of the work site;  
9       (e) transmitting signals representative of the  
10           data to the surface; and  
11       (f) performing the desired tool operation at  
12           the work site location before removing the  
13           tubing from the wellbore.  
14  
15   32. A method of imaging a work site and performing  
16       an end work at the work site in a pre-existing  
17       wellbore during a single trip into the wellbore,  
18       comprising:  
19       (a) conveying a downhole tool into the  
20           wellbore, said downhole tool having an  
21           imaging device for imaging a work site in  
22           the wellbore, a device for isolating the  
23           work site, and an end work device for  
24           performing a desired work at the work site;  
25       (b) isolating the work site;  
26       (c) imaging the work site by the imaging  
27           device; and  
28       (d) operating the end work device to perform a  
29           desired operation at the work site.  
30

1     33.   A method of imaging a location constituting a  
2           work site of interest in a pre-existing wellbore  
3           at which a desired operation is to be performed  
4           without removing the tool from the wellbore,  
5           comprising:  
6           (a)   positioning a downhole tool adjacent the  
7                 work site, said downhole tool having an  
8                 imaging device for sensing properties  
9                 associated with the work site and  
10                generating data representative of the work  
11                site, a transmitter for receiving the data  
12                and transmitting signals representative of  
13                the data to the surface and an end work  
14                device for performing the desired tool  
15                operation;  
16           (b)   generating data representative of the work  
17                 site and transmitting signals  
18                 representative of the data to the surface  
19                 by the transmitter; and  
20           (c)   performing the desired tool operation at  
21                 the work site location before removing the  
22                 tool from the wellbore.  
23

24     34.   A downhole oilfield service tool for imaging a  
25           work site in a wellbore and for performing a  
26           desired operation at the work site without  
27           requiring retrieving the service tool from the  
28           wellbore prior to performing the desired  
29           operation, said service tool conveyable into the  
30           wellbore by a tubing extending from a surface

1 location toward and adjacent the work site,  
2 comprising:  
3 (a) an ultrasonic sensor adjacent a lower end  
4 of the tubing for providing an image of the  
5 work site and generating data  
6 representative said image;  
7 (b) a transmitter associated with the service  
8 tool for receiving the data generated by  
9 the sensor and transmitting signals  
10 representative of said data to the surface;  
11 and  
12 (c) a milling tool adjacent the lower end of  
13 the tubing for performing a cutting  
14 operation at the work site based at least  
15 partially upon said data without retrieving  
16 the service tool from the wellbore prior to  
17 performing the desired operation.  
18  
19 35. A downhole service tool for entering into a  
20 branch wellbore from a juncture at a main  
21 wellbore to perform an end work at a work site  
22 in the branch wellbore during a single trip into  
23 the main wellbore, comprising:  
24 (a) a sensor adapted to obtain data for an  
25 image of the juncture;  
26 (b) a control circuit in the service tool for  
27 receiving the data from the sensor and  
28 transmitting signals representative of said  
29 data to the surface to obtain the image of  
30 the juncture;



1 (c) a tool orientation device in the service  
2 tool, said device adapted to be operated  
3 downhole by the control circuit, to cause  
4 the service tool to enter the branch  
5 wellbore; and  
6 (d) an end work device for performing the  
7 desired end work at the desired work site  
8 in the branch wellbore, whereby the service  
9 tool can locate the juncture, enter into  
10 the branch wellbore from the main wellbore  
11 and perform the desired operation at the  
12 work site in a single trip.  
13  
14 36. The downhole service tool of claim 35, wherein  
15 the tool orientation device is selected from a  
16 group comprising, a knuckle joint that is  
17 controlled from a command from the surface, a  
18 knuckle joint that is controlled downhole, a  
19 plurality of independently adjustable pads, and  
20 a member that extends outward from the service  
21 tool to urge against the wellbore to cause the  
22 service tool to move transverse to the wellbore  
23 axis.  
24  
25 37. A downhole service tool for imaging a selected  
26 work site in a wellbore and performing a welding  
27 operation at the selected work site in a  
28 wellbore during a single trip, comprising:  
29 (a) a sensor adapted to obtain data to image  
30 the work site;

1           (b) a control circuit in the service tool for  
2           receiving the data from the sensor and  
3           transmitting signals representative of said  
4           data to the surface to obtain the image of  
5           work site; and  
6           (c) a welding device in the service tool, said  
7           welding device adapted to be operated  
8           downhole by the control circuit to perform  
9           the welding operation at the work site  
10          during the single trip.

11

12       38. The downhole service tool of claim 37, wherein  
13       the selected work site is selected from a group  
14       comprising a joint between casing in a main  
15       wellbore and a branch wellbore formed from the  
16       main wellbore and a packer.

17

18       39. A downhole oilfield service tool conveyable into  
19       a wellbore for imaging a location constituting a  
20       work site of interest downhole and performing a  
21       testing operation at the work site during a  
22       single trip of the tool in the wellbore, the  
23       tool comprising:

24           (a) a sensor adjacent for sensing properties  
25           associated with the desired work site in  
26           the wellbore and generating data  
27           representative of the work site;  
28           (b) a transmitter for receiving the data from  
29           the sensor and transmitting signals  
30           representative of said data to the surface;

1           (c) a pair of spaced apart seals on the service  
2           tool to seal at least a portion of the work  
3           site of interest between the pair of seals;  
4           and  
5           (d) a testing device in the tool to perform a  
6           selected test in the sealed work site,  
7           during the single trip.  
8

9       40. The downhole service tool of claim 39, wherein  
10       the selected work site is a perforated zone.  
11

12       41. The downhole service tool of claim 40, wherein  
13       the testing device performs a test selected from  
14       the group comprising pressure test of a sealed  
15       region, pressure build-up over a time period,  
16       temperature test, temperature build-up over a  
17       time period, reservoir analysis, formation  
18       evaluation, resistivity of formation fluids,  
19       sample collection, formation fluid analysis, and  
20       hydrocarbon content of formation fluids.  
21

22       42. A downhole oilfield service tool conveyable into  
23       a wellbore for imaging a location constituting a  
24       work site of interest downhole and performing a  
25       workover operation at the work site during a  
26       single trip of the tool in the wellbore, the  
27       tool comprising:  
28       (a) a sensor adjacent for sensing properties  
29       associated with the desired work site in  
30       the wellbore and generating data  
31       representative of the work site;

1 (b) a transmitter for receiving the data from  
2 the sensor and transmitting signals  
3 representative of said data to the surface;  
4 (c) a pair of spaced apart seals on the service  
5 tool to seal at least a portion of the work  
6 site of interest between the pair of seals;  
7 and  
8 (d) a device for injecting a pressurised fluid  
9 into the sealed portion of the work site to  
10 perform the workover operation, during the  
11 single trip.  
12

13 43. The downhole service tool of claim 42, wherein  
14 the work site of interest is a perforated region  
15 and the sealed portion includes at least one  
16 perforation.  
17

18 44. The downhole service tool of claim 42, wherein  
19 the fluid is selected from a group comprising  
20 cement slurry, polymer, water, steam, chemicals,  
21 and acidizing fluids.  
22

23 45. The downhole service tool of claim 42, wherein  
24 the workover operation is selected from the  
25 group comprising injecting fluids into a  
26 perforated zone to improve hydrocarbon  
27 production, sealing of a zone to prevent  
28 production of fluids therefrom, cementing,  
29 fracturing, and cleaning.  
30

- 1     46.   A downhole visual imaging tool for obtaining an  
2           image of a predetermined area of interest within  
3           a wellbore having substantially non-transparent  
4           fluid therein, the imaging tool comprising:  
5           (a)   a tool body conveyable into the wellbore;  
6           (b)   a seal for blocking fluid communication to  
7                 the area of interest, the tool body having  
8                 a device for providing a fluid seal between  
9                 the imaging tool and the work site when the  
10                imaging tool is placed a predetermined  
11                distance from the work site;  
12           (c)   a fluid injection system for displacing the  
13                 non-transparent fluid between the imaging  
14                 tool and the work site with a substantially  
15                 transparent fluid; and  
16           (d)   a camera associated with the imaging tool  
17                 for taking an image of the work site.  
18
- 19    47.   The imaging tool of claim 46, wherein the tool  
20           body is conveyable into the wellbore by a  
21           conveying device selected from a group  
22           consisting of a wireline, a tubing and a  
23           traction device that can move the downhole  
24           imaging tool through the wellbore.  
25
- 26    48.   The imaging tool of claim 46, wherein the camera  
27           is adapted to be remotely oriented in a desired  
28           direction to take an image of the work site.  
29
- 30    49.   The imaging tool of claim 46 further having a  
31           control unit at the surface for receiving data

1           from the camera and for displaying the image of  
2           the work site.  
3  
4       50.   The imaging tool of claim 49, wherein the  
5           control unit controls the operation of the fluid  
6           injection system.  
7  
8       51.   The imaging tool of claim 46 further having a  
9           control circuit within the imaging tool for  
10          automatically controlling the operation of the  
11          fluid injection system and for operating the  
12          camera to obtain the desired image of the work  
13          site according to programmed instructions  
14          provided to the control circuit.  
15  
16       52.   The imaging tool of claim 46, wherein the  
17           imaging tool provides a multi-dimensional view  
18           of the work site from data provided by the  
19           camera.  
20  
21       53.   The imaging tool of claim 46, wherein the fluid  
22           injection system comprises:  
23           (a)   a source of substantially transparent  
24               fluid; and  
25           (b)   a fluid transfer mechanism for displacing  
26               at least a portion of the substantially  
27               non-transparent fluid with the  
28               substantially transparent fluid wellbore.  
29  
30       54.   The imaging tool of claim 53 further having a  
31           fluid communication line coupled to the fluid

1 chamber for retrieving the substantially  
2 transparent fluid from the wellbore into the  
3 fluid chamber.  
4

5 55. The imaging tool of claim 54, wherein the fluid  
6 transfer mechanism is coupled to the fluid  
7 communication line for causing the substantially  
8 transparent fluid to flow from the wellbore into  
9 the fluid chamber.  
10

11 56. The imaging tool of claim 46, wherein the device  
12 for providing the seal is a packer.  
13

14 57. A method for imaging a work site of interest  
15 located within a wellbore below a surface  
16 location, the wellbore containing a  
17 substantially non-transparent fluid therein,  
18 said method comprising:  
19 (a) setting a fluid seal a predetermined  
20 distance above the work site;  
21 (b) displacing the substantially non-  
22 transparent fluid between the work site and  
23 the seal with a substantially transparent  
24 fluid; and  
25 (c) taking an image of the work site with a  
26 camera placed between the seal and the work  
27 site.  
28

29 58. A method for imaging a work site of interest  
30 located within a wellbore containing a

1 substantially non-transparent fluid therein,  
2 said method comprising:  
3 (a) conveying an imaging tool within the  
4 wellbore to a location above the work site;  
5 (b) isolating and utilising at least one seal  
6 of the work site;  
7 (c) displacing the substantially non-  
8 transparent fluid in the work site with a  
9 substantially transparent fluid; and  
10 (d) obtaining an image of the work site with  
11 the imaging tool.

12  
13 59. The method of claim 58 further having a circuit  
14 within the imaging tool for communicating the  
15 image to a surface location.

16  
17 60. An imaging tool for obtaining an image of a work  
18 site of interest within a wellbore, comprising:  
19 (a) a tool body conveyable into the wellbore;  
20 (b) a flexible inflatable device on the tool  
21 body having a plurality of spaced sensors  
22 arranged at a plurality of predetermined  
23 surface locations on the inflatable  
24 flexible device, each such sensor providing  
25 a signal in response to deformation of the  
26 surface locations of the flexible  
27 inflatable device at which such sensor is  
28 placed relative to a predetermined norm for  
29 such sensor; and  
30 (c) a computer, said computer receiving signals  
31 from the sensors in the plurality of



1           sensors when the inflatable flexible device  
2           is inflated and urged against the work site  
3           and in response thereto providing an image  
4           of the work site.  
5  
6       61.   The imaging tool of claim 60, wherein the  
7           computer is located at a surface location.  
8  
9       62.   The imaging tool of claim 60, wherein the  
10          computer is located within the imaging tool for  
11          computing the image of the work site downhole  
12          during operation of the imaging tool.  
13  
14       63.   The imaging tool of claim 60, wherein the  
15          imaging tool transmits data to the computer  
16          representative of an image of the work site  
17          determined from the sensors in the plurality of  
18          sensors.  
19  
20       64.   The imaging tool of claim 60 further having a  
21          fluid injection system for injecting a fluid  
22          into the inflatable flexible device.  
23  
24       65.   A downhole oilfield service tool for imaging a  
25          work site in a wellbore and for performing a  
26          desired operation at the work site during a  
27          single trip of the service tool conveyed into  
28          the wellbore by a tubing extending from a  
29          surface location toward and adjacent to the work  
30          site, comprising:

- 1           (a) an imaging device adjacent a lower end of
- 2           the tubing for providing an image of the
- 3           work site; and
- 4           (b) an end work device adjacent the lower end
- 5           of the tubing for performing the desired
- 6           operation at the work site based at least
- 7           partially upon the image of the work site
- 8           during the single trip of the service tool
- 9           in the wellbore.

1     CLAIMS

2

3     1.    A downhole service tool, comprising:

4           (a)   a packer adjacent a lower end of the tool, said  
5                packer having a packing member on a housing  
6                that forms a seal between the housing and a  
7                work site in a pre-existing wellbore when a  
8                fluid is injected into the packing member; and

9           (b)   a sensor uphole of the packer for providing  
10                data representative of an image of the work  
11                site when the downhole tool is conveyed into  
12                the wellbore for setting the packer in the  
13                wellbore.

14

15     2.    A downhole service tool as claimed in Claim 1 and  
16            substantially as hereinbefore described with  
17            reference to the accompanying drawings.



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Application No: GB 0025855.8  
Claims searched: 1

Examiner: David Pepper  
Date of search: 11 December 2000

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): E1F FHU

Int Cl (Ed.7): E21B

Other: Online: WPI, EPODOC, JAPIO

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | Relevant to claims |
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